ANCIENT HEALTH

Skeletal Indicators of Agricultural and Economic Intensification

Edited by Mark Nathan Cohen and Gillian M. M. Crane-Kramer

Ancient Health

Bioarchaeological Interpretations of the Human Past:
Local, Regional, and Global Perspectives

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Bioarchaeological Interpretations of the Human Past:
Local, Regional, and Global Perspectives

This series examines the field of bioarchaeology, the study of human biological remains from archaeological settings. Focusing on the intersection between biology and behavior in the past, each volume will highlight important issues, such as biocultural perspectives on health, lifestyle and behavioral adaptation, biomechanical responses to key adaptive shifts in human history, dietary reconstruction and foodways, biodistance and population history, warfare and conflict, demography, social inequality, and environmental impacts on population.

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and Gillian M. M. Crane-Kramer

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Foreword

Although archaeological human remains have long been the focus of scientific investigation, their centrality in the study of the human past has only recently developed. Aside from physical anthropologists, few others saw the importance of skeletons for addressing questions about earlier cultures. If reported at all, results of detailed analyses of archaeological human remains were often relegated to appendices of site reports, going largely unread except by a few specialists or the very curious.

When I began my professional career in the early 1980s, archaeological human remains began taking on a much more important role for testing hypotheses about earlier societies. At that point, leaders in bioarchaeology, as the subject has become known, were well into constructing regional syntheses of health and biocultural adaptation, focusing on human remains as a primary source for addressing interesting questions and hypotheses. Exemplary in this regard were the research programs directed by Jane Buikstra and colleagues in the lower Illinois Valley and George Armelagos and colleagues in Sudanese Nubia. Their investigations emphasized areas of study now routinely investigated by bioarchaeologists around the world, including diet and nutrition, bone chemistry, health, growth and development, demography, activity, violence and warfare, population history and biodistance, and social inequality. Their regional studies helped to build the argument that skeletons offer a powerful resource for addressing anthropologically driven issues of interest to both physical anthropologists and archaeologists, especially with regard to human adaptation and behavioral inference.

Over the past two decades, there has been a proliferation of publication of research in bioarchaeology, including monographs and books. Although these were largely North American in orientation, significant publications now represent all corners of the globe. This burgeoning literature suggests that the time has come for a new book series drawing on the rich fund of data provided by the study of human remains from archaeological contexts.

This volume launches Bioarchaeological Interpretations of the Human Past: Local, Regional, and Global Perspectives, a new series published by the University Press of Florida focusing on bioarchaeology. The central motivation for each book in the series is to address questions and hypotheses that help inform our understanding of past societies. The books especially focus on the intersection between biology and behavior, highlighting important current issues

in the field, such as biocultural perspectives on health, lifestyle and behavioral adaptation, biomechanical responses and lifestyle, dietary reconstruction, mobility and resource use, population history, warfare and conflict, demography, social inequality, and environmental impacts on people.

More than twenty years have elapsed since the publication of Mark Nathan Cohen and George J. Armelagos' landmark edited book, *Paleopathology at the Origins of Agriculture.* This 1984 volume made the strong case that—contrary to popular notions about the positive impact of the domestication of plants and animals on the human condition—agriculture and settled life had a profoundly negative impact on health and well-being. Measures of health (for example, enamel defects, infection, and other indicators of stress) in most of the nineteen studies presented identified temporal declines in health. Although several earlier investigations had documented evidence of increased stress and decline in quality of life in the shift from foraging to farming, their volume drew attention to this major adaptive shift and its health consequences. Like the aforementioned research programs, Cohen and Armelagos' book helped spawn an entire generation of bioarchaeologists who have devoted their efforts to the investigation of the lives and lifestyles of past people.

I am pleased to launch the new book series with *Ancient Health: Skeletal Indicators of Agricultural and Economic Intensification*, edited by Mark Nathan Cohen and Gillian M. M. Crane-Kramer. Inspired by new methods, new regional investigations, and a much wider discussion of the costs and consequences of the foraging-to-farming transition and economic intensification, this book is the intellectual descendant of the 1984 classic. While declines in health are documented in a number of settings covered by the various contributors, the new volume makes abundantly clear that quality of life and well-being generally are more complex than was previously imagined. It also makes clear that the decisions made by humans regarding resource acquisition have long-term consequences, positive and negative. Bioarchaeology has much to offer to these and related discussions in anthropology.

Clark Spencer Larsen
Series Editor

Preface

This volume is a twentieth-anniversary update of studies reported in *Paleopathology at the Origins of Agriculture* (Mark Nathan Cohen and George J. Armelagos, eds., 1984). Participants for this conference were selected by open invitation to both established scholars and graduate students on the basis of their ability to address the research questions and the common, parallel style of research and presentation. The conference was held in Clearwater Beach, Florida, in April 2004, and final revised papers were submitted by September 2006. We wish to thank the Wenner-Gren Foundation for primary funding and a minigrant from the State University of New York at Plattsburgh for secondary funding. We also wish to acknowledge the excellent cooperation of the Holiday Inn Sunspree in Clearwater Beach, Florida, and the support and assistance of Susan Spissinger, Colleen Bernard, Virginia Johnson, and Megan Duffy of Plattsburgh State University College as well as Patricia Higgins and Stephen Kramer.

Abbreviations

AD	Anno Domini
Adu.	Adult
AMTL	Antemortem tooth loss
Ant.	Anterior
AR	Alveolar resorption
Arth.	Arthritis
BA	Bronze Age
BP	Before Present
CO	Cribra orbitalia
df	Degrees of freedom
DJD	Degenerative joint disease
EH	Enamel hypoplasia
F	Female
Hell.	Hellenistic period
HG	Hunter-gatherer
HL	Harris lines of growth arrest
IA	Iron Age
Inf.	Infection
Juv.	Juvenile
LEH	Linear enamel hypoplasia
M	Male
Med.	Medieval period
Meso.	Mesolithic
MNI	Minimum number of individuals
N	Number (full sample size)
n	Number (subsample size)
Neo.	Neolithic
PH	Porotic hyperostosis
Post.	Posterior
PR	Periosteal reactions
Rob.	Robusticity
SD	Standard deviation
TB	Tuberculosis
TMJ	Temporomandibular joint
Trep.	Treponemal infection

Individual chapters include abbreviations for their own site names, explained in text. Abbreviations in tables and figures are given in table footnotes and captions, respectively.

Introduction

MARK NATHAN COHEN

The significance of archaeology extends far beyond its ability to define specific cultural sequences such as the emergence of complex society in Peru. Combined with fields such as ethnography and history, it transcends local boundaries and molds our perception of human experience and the trajectory of human cultural evolution.

We now can perceive a sequence of events broadly shared by many human populations. Against a gradual increase in the size and density of human populations, we see the following elements (very roughly in order): geographical expansion; limits on the territory of each group; a broadening spectrum of resources utilized; the transition from mobile to sedentary populations; the domestication of resources; "intensification" of resource use; increasing size and nucleation of villages and cities; increasing cultural and social "complexity" and hierarchy; the rise of economic specialists; the rise of centralized leadership and social stratification; definition of society by geographical boundaries rather than ethnic ones; and the emergence of government by force.

Recognizing this common trajectory has enabled us to form broad theories about how and why such changes occurred. Until recently, we assumed that change meant new technology, resulting in improved quality of life—that is, cultural evolution meant "progress," dependent only on human ingenuity.

Archaeology also can challenge such models. In recent years, paleopathology has posed significant challenges to these paradigms, to our sense that human lives have generally improved through time, and to the presumed causes of cultural evolution, shifting our focus from inventions (such as the "invention" of agriculture) to adjustments to economic, demographic, or political pressures, often with negative consequences for people's lives.

A Brief History of Quantitative Paleopathology

Comparative quantitative studies of paleopathology began to accumulate in the late 1970s, and a sense of negative health trends in archaeological sequences began to emerge (Buikstra and Cook 1980; Lallo et al. 1978; Larsen 1982).

In a 1982 conference, the proceedings of which were later published as *Paleopathology at the Origins of Agriculture* (Cohen and Armelagos 1984), scholars presented nineteen studies of pathology frequencies in sequential populations in various regions of the world. The studies focused on the "intensification" of

hunting and gathering economies, the adoption and intensification of farming, and the emergence of social stratification and political force. (The term *intensification* refers to increases in caloric production per unit of land.) We were looking for trends in health in each region, which we hoped would allow us to identify parallel health trajectories in the various regions. The range of local environmental, cultural, and political variables was too great, however, and the number of samples too small, for us to identify correlations of those variables with changing health. Individual examples of correlation mean nothing except, of course, in their local context. General conclusions require repeated instances of co-occurrence of health and specific geographical or cultural variables. Such correlations were noted but not considered a basis for broad theorizing. Instead, we used our many studies to "wash out" local variables.

We addressed two major theoretical propositions: first, that the adoption of agriculture resulted from need and stress, not invention and choice; and second, that the trajectory of human health represented decline, not progress. Our data largely confirmed the second proposition (and by implication the first). Among skeletal pathologies, anemia and both nonspecific and specific infections (such as yaws and tuberculosis) commonly increased in frequency through time and/or with economic intensification, as did indicators of severe episodic but unspecified stresses in children (dental linear enamel hypoplasia [LEH] and dental microdefects). Caries increased markedly and consistently with the adoption of farming. Sporadic reports of diminished tooth size, diminished stature, reduced childhood osteoporosis, and childhood growth rates tended to support the argument for declining health. Studies of trends in trauma, physical stresses, robusticity, and arthritis produced mixed results. Studies of paleodemography often appeared to demonstrate declining life expectancies.

That book also established a style of controlled comparative analysis of prehistoric pathology sequences that has had a significant impact on later work. Subsequent volumes have used the style of comparative analysis to generalize about particular diseases such as treponemal infection or syphilis (Dutour et al. 1993), leprosy (Roberts et al. 2002), and tuberculosis (Roberts and Buikstra 2003); about particular regions and periods, such as postcontact North America (Verano and Ubelaker 1992; Larsen and Milner 1994) and early prehistoric Europe (Bennike et al. 2002); and about health patterns related to sex and gender (Grauer and Stuart-Macadam 1998).

The collection by Steckel and Rose (2002) is the most important of these projects. It used standardized methods of data reporting (Buikstra and Ubelaker 1994) to assess the relative health of populations in various parts of the New World, permitting interregional comparisons and the rough ranking of populations on a defined index of health. Its database permits observations that are invisible or insignificant on the local scale.

Some Challenges to the First Volume

A number of challenges and criticisms of Cohen and Armelagos (1984) have been offered, however. The first six in the following list were recognized in the Cohen and Armelagos volume or are post hoc, referring to patterns of data and standards of analysis and interpretation that became available only after that collection was published. Techniques had not yet been standardized. There were few sequences and archaeological horizons available for analysis. Many of these shortcomings have been addressed in subsequent work by many scholars and in this volume. The criticisms include assertions

- that the sequences do not demonstrate the propositions as clearly as claimed and that counter-examples are known;
- that the studies were skewed toward North America;
- that the data often failed to pinpoint the adoption of agriculture or to represent the full temporal and economic range of each sequence;
- that techniques utilized in identifying pathologies were not uniform, preventing comparisons of one region to another;
- that studies did not tease out the effects on health of individual variables such as demography, sedentism, nucleation of settlements, plant or animal domestication, foraging versus agricultural economies, centralized governments using force, and social stratification (see Rose et al. 1984);
- that fined-tuned histories of economic behavior and health were not provided;
- that attempts to reconstruct the life expectancy of a population based on its cemetery were inherently flawed, which discredits conclusions about paleodemography;
- and that quantitative analysis of pathology in cemetery populations presented in Cohen and Armelagos lacked sophistication and might present misleading descriptions of the health of the populations within the cemeteries they represent (see, particularly, Wood et al. 1992).

In regard to the latter criticism, we argue, however, that under most circumstances, pathology frequencies in cemeteries *are* representative of *relative* frequencies of pathologies in the once-living populations (see Appendix A).

Review of Subsequent Reports

Paleopathological data available through 1988, largely supportive of the 1984 conclusions, are summarized in Cohen 1989. Data from more recent studies, gleaned from the bibliography *Human Paleopathology and Related Subjects* (through Supplement 8), have largely reinforced the patterns described in Cohen and Armelagos 1984 and Cohen 1989. For additional studies from the New

World, see Armelagos et al. 1991; Bocquet-Appel and Naji 2006; Buikstra 1992; Danforth et al. 2002; Dietz and Bergfield 2001; Drusini 1991; Giesen 1992; Hutchinson and Larsen 1988; Kent 1986; Lambert 1993; Larsen 1995, 2000a, 2002; Larsen and Harn 1994; Larsen et al. 2002; Márquez Morfín et al. 2002; Martin 1994; Milner 1991; Monahan and Weaver 1996; Rose et al. 1991; Ruff 1987; Sciulli and Overby 2002; Ubelaker 1992; Ubelaker and Newson 2002; Vargas 1990; Verano 1992; Walker 2005; White 1990; and Williams 1994a, b. For the Old World, see, for example, Agelarkis and Waddel 1994; Al-Abbasi El-Din and Sarie 1998; Bocquet-Appel and Naji 2006; Constandse-Westerman and Newell 1984; Dobson and Carper 1996; Duran et al. 1997 (with reference to improving health with declining social complexity, not time sequence); Formicola 1987; Froment 2002; Haduch 2002; Lovell and Kennedy 1989; Lukacs 1992; Lukacs and Minderman 1990; Maat 2005; Manzi et al. 1997, 1999; Oxenham 2002; Palfi 2002; Pechenkina et al. 2002; Roberts and Buikstra 2003; Roberts and Cox 2003; Roberts and Lewis 2002; Roberts and Manchester 2005; Salvedi et al. 2001; Sobolik 2000; Stuart-Macadam 1991; Suzuki 1991; Walker and Thornton 2002; and Webb 1995.

Several studies have confirmed the work of Meiklejohn and colleagues (1984) in finding a decline in human stature from the Paleolithic through the Mesolithic to the Neolithic and beyond in the Old World. These include Crubézy et al. 2002; Froment 2002; Piontek and Vancata 2002; Waldron 1989. Froment (2002) also has reported isotopic evidence reinforcing the idea of the Mesolithic "broad-spectrum revolution" and a concomitant decline in dietary quality in the Neolithic in Europe. Bennike (1985) reported relatively small statures for Mesolithic populations and a general increase in stature to the Late Neolithic, followed by a decline in stature until the modern period in Scandinavia. Y'Edynak (1989) summarized patterns of declining tooth size from the Paleolithic through the Neolithic in several parts of Europe and the Middle East. (See also Ahlström 2003; Brace et al. 1987; Kieser 1990; Lukacs and Hemphill 1991.) For the New World, see Wrobel 2003; Hinton et al. 1980; Smith, Smith, and Hinton 1980, and for stature, see Danforth 1999a and Márquez Morfín and del Angel 1997.

Changes in stature and tooth size and mortality patterns (Bocquet-Appel and Naji 2006) provide most of the evidence that we have for (apparently declining) health prior to the adoption of farming (although these measures have also been interpreted in different ways; see the editors' conclusions to this volume). These data have, to a great extent, modified or even reversed the once-prevailing "progress" paradigm. The proposition of health decline in prehistory appears to have become the accepted paradigm among prehistorians and, increasingly, historians (for example, Curtin 2002)—at least, the burden of proof has been reversed. But of course the data remain incomplete; the jury is still out.

Counterexamples exist, but they are sporadic or provide only relatively minor or partial contradiction to the patterns discussed above. In the Old World, Lillie (1996) found little evidence of health (or significant economic) change from the Mesolithic to the Neolithic in the Ukraine. Meiklejohn and Zvelebil (1991) found little change or mixed changes in health patterns between the Mesolithic and the Neolithic in western Europe. Jackes and colleagues (1997) obtained mixed results in their study of changes in health from Mesolithic to Neolithic populations in their sequence from Portugal involving uncertain patterns of economic and settlement change, but their estimates of changing fertility and population growth rates suggest a significant increase in mortality across the transition. Lalueza-Fox and Gonzalez Martin (1999) found a general and significant decrease in dental pathology from Mesolithic times through the twentieth century AD on the Iberian peninsula. Blau (1999a,b) found higher rates of various pathologies at the earlier but politically more complex Umm an-Nar phase than in the later but simpler Wadi Suq period in the United Arab Emirates. Power (1993) described a seesaw pattern of health, involving different indicators in Ireland from the Neolithic through the Medieval period. Pietrusewsky and colleagues (1997) saw possible improvement in health through time on the Mariana Islands. Fairgrieve and Molto (2000) found an improvement in health from pre-Roman to Roman periods at the Dakleh Oasis in Egypt. Lovell and Whyte (1999) found a decline in hypoplasia rates following the Old Kingdom in Egypt that they relate to known very bad climate conditions in Egypt during the Old Kingdom. Yamamoto (1992) reported a mixed trend in hypoplasia from the Jomon through the Edo period in Japan. Shigehara (1994) describes generally declining rates of hypoplasia from the Jomon period to modern times in Japan, until the Edo period. Most dramatically, Eshed and colleagues (2004a) suggested that life expectancy increased from Natufian hunter-gatherers to early farmers in the Levant.

Among New World populations, Benfer (1990) reported a sequence displaying improving health in preagricultural Peru. (However, see the Peru chapter by Pechenkina and colleagues in this volume.) Neves and Wesolowski (2002) found declines in enamel hypoplasia and anemia (porotic hyperostosis) from preceramic to ceramic sites in Brazil. Hinton and colleagues (1980) found teeth declining in size as stature increased in prehistoric Tennessee. Owsley (1991) found an increase in cortical thickness of bone that he relates to an increase in nutritional quality from the prehistoric to protohistoric populations of the North American Great Plains. Hodges (1987) found no significant change in frequencies of pathology with the intensification of agriculture in Oaxaca. Stodder and colleagues (2002) describe a complex pattern of pathological change in the American Southwest. Patterson (1986) found mixed trends in oral health in late prehistoric Ontario. Katzenberg (1992) also found mixed trends in health in Ontario but with infection rates, particularly those of se-

vere infection, including tuberculosis, generally increasing through time. The worst health was experienced in the incipient agriculture group, after which health rebounded. Hutchinson (1992) found that the frequency of hypoplasia decreased but the duration of events increased in a comparison of hunter-gatherers and farmers in the southeastern United States. Scott (1979) reports on a nine-thousand-year sequence of increasing tooth size in Peru. (See also summaries in Scott 1979 and in Harris et al. 2001, which detail various trends in other regions.) White (1997) records rates of hypoplasia declining from the Preclassic to the Early Classic among the Maya, followed by increases to equal or higher levels in the terminal Classic and Postclassic periods. Wright (1997) found no deterioration of health over time in her Maya sample.

Note, however, that most comparisons of hunter-gatherers and farmers use fairly late Mesolithic/Archaic hunter-gatherers. Comparisons between earlier Paleo hunter-gatherers and farmers might reveal health differentials greater than they now appear. Paleo populations should, by theory (Cohen 1989) and the evidence of stature and tooth size, have been healthier than their "Meso" descendants (this argument has also been made from an analysis of world demographic patterns by J.-P. Bocquet-Appel; pers. comm. and Bocquet-Appel and Naji 2006).

The most telling argument for overall decline in health with the development of farming (reflected in increased mortality) is the mathematics of compound population growth (analogous to compound interest). We know that no matter what reasonable estimates of world population at the time of the origins of agriculture are used, population growth from the beginning of sedentary farming to the age of Columbus must on average have been extremely slow (perhaps 0.1 percent per year). If, as has been commonly assumed—and some such as Bocquet-Appel and Naji (2006) would argue, demonstrated—average fertility increased after the adoption of agriculture, mortality must also on average have increased to result in the very slow population growth for the period in question. This is a very powerful argument for declining health.

But that does not mean that either fertility or mortality rates remained constant throughout this period. Bocquet-Appel and Naji (2006; Bocquet-Appel, pers. comm.) argue that increasing fertility led to a population growth surge, typically within six hundred to eight hundred years of the adoption of sedentary farming, after which population growth leveled off again, probably as a function of increasing mortality. Their data come from both the New World and the Old World. Various chapters in Bellwood and Renfrew 2003 argue that rapid expansion of some populations after the adoption of farming was responsible for the rapid spread of certain language families. The point is not that either argument cannot be true. The point is that every temporal surge or regional expansion by particular populations had to have been offset by almost

equal declines or failures of other populations. For most times and places, after the adoption of farming, increasing mortality is implied.

Improvements in Methodology and Interpretation

Since the publication of Cohen's 1989 volume, methods, techniques, and interpretations in skeletal pathology have changed and improved. Techniques and diagnoses have been standardized (for example, Buikstra and Ubelaker 1994; Katzenberg and Saunders 2000; Steckel and Rose 2002). Naïve reconstructions of life expectancy have largely been abandoned—as a result of criticisms by many scholars, although more tempered reconstructions of paleodemographic parameters are still attempted. Isotope studies now help reconstruct diet, geographical variation, and geographic origin and migration of individuals. Trace-element studies, now widely criticized, play a much smaller role.

DNA studies and work in immunology now enable us to identify specific diseases in prehistoric skeletons: cholera, tuberculosis, leprosy, syphilis, bubonic plague, malaria, Chagas disease, influenza, ascariasis, and schistosomiasis (Greenblatt and Spigelman 2003). The studies can enormously expand our knowledge of the history and distribution of specific prehistoric diseases by identifying the presence of disease in areas where skeletons display no pathology, by strengthening paleopathological diagnoses based on gross pathology, and by determining the ratio of visible pathology to the actual prevalence of disease in a cemetery population. At present, however, such studies are prohibitively expensive for other than the most pioneering work.

Some interpretations of pathology have also changed. In particular, Cook (summarized in her chapter in this volume) has pointed out that periosteal reactions (PR) do not necessarily reflect infection unless other diagnostic features are present. Many scholars have now noted that porotic hyperostosis (PH) of the skull and cribra orbitalia (CO) of the eye sockets, once considered diagnostic of iron-deficiency anemia, may also represent scurvy. Differentiation of the two based on the distribution of porosity may be possible.

This Volume

In designing this conference, we explicitly increased the geographical range of areas analyzed. Twenty studies are presented here, provided by individuals from eight countries. The twenty regions covered include five areas of the eastern, central, and southern United States; Mexico, Chile, and Peru; Denmark, England, and Portugal; South Africa; the United Arab Emirates; Bahrain, South Asia, and the Levant; and China, Mongolia, Malaysia, and Thailand. Another sequence from Vietnam was presented at the conference and is cited

but not included here. Obviously, large areas of the world are not represented, although (as indicated above) reports on some additional areas have been published elsewhere. Our goal of broadening the geographical range of studies accounts for the wide geographical dispersal of the samples and the fact that not all of the studies use the latest standards, understandings, and technologies. These studies should be read as suggesting the availability of data and degree of sophistication in each area. In some cases, data were gathered and reported before new techniques were developed and measurements were standardized. Some studies are included very specifically as introductions to pioneering work in little-known regions. The book should be read with the understanding that it was planned as a geographical supplement to existing work.

In searching for new work, we solicited papers publicly in several venues in all hemispheres, specifically inviting the work of young scholars and excluding areas described in the Cohen and Armelagos volume, unless work in the particular area had changed substantially. Unfortunately, invitations actually spread mostly by word of mouth.

The substantive chapters are followed by a discussion by the editors summarizing and comparing data and sequences from the various regions (in both text and graphs) and incorporating comments made by members of the symposium. Issues of interpretation are discussed in the final summary and appendix.

The data presented include the measures of health used elsewhere: size of juvenile and adult teeth, antemortem tooth loss (AMTL), dental wear, caries, and dental enamel hypoplasia (EH or LEH depending on pattern); porotic hyperostosis (PH); periosteal reactions, osteomyelitis, and signs of specific infections, including tuberculosis, leprosy, treponemal infections, and others; stature and patterns of growth; and trauma, arthritis, osteoporosis, and robusticity of bone.

Data are presented by region. Five papers are significant updates of work reported in the 1984 volume. For those interested in tracing cross-regional patterns of particular skeletal markers, a detailed index provides reference to a specific indicator, region by region. Trends are also compared in graphs in the conclusions.

Actual radiocarbon dates are presented in the format presented by individual authors. Dates reflecting estimated time spans derived from radiocarbon dates, however, are always presented as BP. Dates obtained from historical documents are represented by BP and by BC/AD dates. Descriptions of the etiology of specific pathologies are omitted (unless considered controversial) both to avoid redundancy and because readers of this book are probably well acquainted with them. We omit data on life expectancy calculated from cemeteries unless explicit attempts have been made to address the problems.

Because of the difficulty of finding sites specifically focused on the origins of agriculture, we expanded our focus to include any sequence of technological, social and political change, or economic intensification. Predictably, different chapters describe different pieces of prehistory visible in different regions. As Cohen and Armelagos noted, each archaeological site or layer is a snapshot of an ongoing process. And different snapshots are available from different regions. As a result of this and the still-small sample sizes, comparison of specific events between regions are prohibitively difficult. However, some patterns that can be generalized are discussed in the conclusions.

We should also note that the number of studies included in this volume imposed extreme space constraints. As a result, presentations of raw data have often been given short shrift. The extensive bibliography provides the sources of raw data and statistics and more detailed descriptions from which conclusions are drawn. These chapters are summaries and keys to the much more detailed literature.

Our goals are explicitly different from those of Steckel and Rose. We believe that standardization of techniques across workers may be impossible to achieve fully even when guidelines are provided (see, for example, Jacobi and Danforth 2002; Jacobi et al. 2004). We prefer to rely more on the standardization implicit in having the same individual or team doing the scoring within a defined region. Also, we argue that comparisons within one geographical area are more valid than those applied cross-regionally that have problems of greater genetic and environmental differences between populations and greater chance for interobserver error. It seems more important to note that stature declines in much of Mesoamerica than to compare Mesoamerican stature to that of different and distant populations.

Because of these goals and the problems inherent to a global presentation of data, each of the regions described in this book should be read initially as an individual unit, with an eye to trends within its own sequence. Secondarily, the individual regional trends can be compared to one another and to trends visible in other regions. Ultimately, of course, all work in paleopathology should be read as contributions to our understanding of cultural evolution.

1

Maize and Mississippians in the American Midwest

Twenty Years Later

DELLA COLLINS COOK

This chapter updates my contribution to *Paleopathology at the Origins of Agriculture* (Cohen and Armelagos 1984). We know a great deal more now about the incorporation of maize into the diet than we did twenty years ago, and we know a great deal more about the attendant political, social, and economic changes that accompanied what one might call Mississippianization in the midcontinent. To reveal some of the additions to our collective knowledge, I shall focus on Cahokia and its hinterlands in west-central Illinois (see Table 1.1 for a summary of periods for the sites discussed in this chapter).

Cahokia—a site comprising over one hundred mounds, palisades, and many satellite communities—was the largest prehistoric settlement in North America north of Mexico. It is situated at the north end of the American Bottom, a wide floodplain lying east of the Mississippi River and extending one hundred kilometers south from present-day St. Louis, Missouri; it was at its height between 1000 AD and 1250 AD (Milner 1998). Its chronology is complicated by the persistence of Woodland adaptations in Cahokia's hinterlands.

Food Production

The incorporation of maize into the diet was quite slow in west-central Illinois. The concept of an agricultural revolution does not fit well in the midcontinent, as both Cassidy and I noted in the conference volume (Cohen and Armelagos 1984). Intensive exploitation of nuts and acorns appeared in the Archaic and continued into historic times, and maple sap may represent a less visible but important source of energy (Gardner 1997; Munson 1988, 1989). Food-producing economies based on native squash and gourds, sunflowers, and small oily and starchy seeds were established in Archaic times, and small grains (notably chenopod, knotweed, maygrass, and what is called little barley grass) were staple garden crops during the Middle and Late Woodland periods in Illinois (Yarnell 1994: 12). Maize was known to Middle Woodland gardeners 2,000 years ago (Riley et al. 1994; Bender et al. 1981), but it did not become an

Table 1.1. Chronology of Cahokia-Area Sites

Period	Date Range
Middle Archaic	8000–5000 BP
Late Archaic	5000–2600 BP
Early Woodland	2600–2150 BP
Middle Woodland	2150–1700 BP
Early Late Woodland	1700–1250 BP
Late Late Woodland/Emergent Mississippian	1250–1000 BP
Mississippian	1000–600 BP

important food plant for another 750 years. It may have been traded into the Midwest rather than grown locally. Beans, the third element of what some once called a Mesoamerican triad, were introduced quite late, after Mesoamerican cucurbits and amaranths and long after maize (Lopinot 1994).

Maize, permitting larger population aggregates, is for many scholars synonymous with agricultural intensification (Cook 1979; Schurr and Schoeninger 1995). Cahokia certainly represents a large population aggregate, although population estimates are notably difficult and controversial. However, even conservative estimates suggest a population of approximately 20,000 during Early Mississippian times for the American Bottom, including Cahokia (Milner 1998). Less attention has been paid to estimating population in Cahokia's hinterlands, but relative depopulation of frontier zones between the major Mississippian polities is probable.

Some Late Woodland and Emergent Mississippian sites in the uplands surrounding the American Bottom lack evidence of maize cultivation, indicating a continuing reliance on small-seed cultivation for a portion of the economic system (Fortier and Jackson 2000).

For Lopinot (1994), agricultural intensification is reflected in multicropping of fields with maize and small-seed crops that coincided with the high point of the Cahokia population in Early Mississippian times. In Late Mississippian times, during the long decline and collapse of Cahokia, maize production and a reliance on forest products, particularly nuts, increased at the expense of starchy seeds (Lopinot 1994: 143).

Some communities in the hinterland persisted in small-seed cultivation throughout the rise and fall of Cahokia (Wright 2003). Others, however, engaged in various levels of maize cultivation, often well before they began to participate in the Mississippian cultural complexity.

Late Woodland peoples in what became Cahokia's sphere of influence were remarkably insular. Pottery types were highly localized in the Sny Bottom and the lower Illinois Valley north of Cahokia, with the implication that each represents a distinct community (O'Gormann and Hassen 2000; Studemund

2000). Late Woodland sites in the American Bottom around Cahokia are less differentiated, vessel shapes and design elements more diverse and elaborate (Fortier and Jackson 2000). Even this relatively cosmopolitan local variation on Late Woodland monotony contrasts with the free movement of goods and ideas that appears to characterize the Mississippian polities of the central Mississippi and lower Ohio valleys. Whether the peak population of Cahokia was 30,000 or 8,000, the center integrated religious, political, and economic activities that had previously been local and isolated.

Diet

Human bones represent a somewhat different picture of food production. At the time of the Paleopathology at the Origins of Agriculture conference, carbon isotope studies were in their infancy. Data were available on only forty-five individuals from nine sites for west-central Illinois (van der Merwe and Vogel 1978; Bender et al. 1981). Since then, isotopic fractionation studies have become the most common chemical analysis of ancient bone in the region.

Synchronic variation in maize use emerged as an issue as soon as sizable samples were tested. At the same time, stable zinc values suggested continuous use of meat (Buikstra et al. 1987, 1994). Broad regional patterns suggest a gradual and more-or-less smooth increase in maize use through time (Buikstra 1992), but local patterns have remained highly variable.

One vexing issue has been laid to rest. Archaeobotanical evidence for Middle Woodland maize had been known for many years, but tiny quantities of plant remains and a lack of dental caries led many to doubt that the plant remains were properly related to Middle Woodland contexts. We now know that maize is of Middle Woodland age, because plant remains from the Holding site in the American Bottom have been directly dated. But carbon isotope studies on human bone show no maize use, perhaps because very low levels of maize consumption mask isotope visibility (Riley et al. 1994; Buikstra et al. 1994). Maize consumption may have been quite restricted or even ceremonial (Fortier and Jackson 2000), and maize may well have been an exotic resource traded from warmer regions, but sourcing studies on maize in this region have not been done.

Our picture of maize consumption at Cahokia is limited because excavated cemeteries are few and preservation is poor. Nonelite burials from the Kane Mounds, the East St. Louis Stone Quarry (Buikstra et al. 1994), Hill Prairie, and Corbin (Hedman et al. 2002)—all Mississippian sites in the American Bottom peripheral to Cahokia—have been studied. Data from Cahokia itself are confined to excavations from one mound, an early and complex elite mortuary

structure. Studies have documented important diagenetic effects on carbon isotope fractionation that underestimate maize use in poorly preserved bone (Buikstra et al. 1994). Elite male and female burials show lower maize use than do female mass (possibly sacrificial) burials. Female mass burials show higher rates of porotic hyperostosis and dental caries than do the elite burials. Nitrogen fractionation studies and carbon isotope studies of bone apatite and collagen show that the individuals found in elite burials ate more meat. Plants other than maize provided most of the protein for the females in mass burials (Buikstra et al. 1994; Ambrose et al. 2003). Maize consumption in some of these women was higher than in any other communities within Cahokia's sphere of influence, suggesting low social status. The closest ethnographic parallels to these sacrifices might be the Pawnee Morning Star sacrifice and the coastal Southeast, although there the victims were not of low social status (Driver 1961). Another possibility is that persons intended for sacrifice were fed a diet high in maize as a sign of honor, as was the case in the Tezcatlipoca sacrifice in Aztec Mexico.

Schober has added eighty-seven nitrogen, collagen, and apatite analyses to the data available for the lower Illinois Valley. They show higher variability in maize use in Late Woodland samples than were expected (Schober 1998). Most surprising was Schober's discovery that the people of the Schild component from the latter half of Late Woodland times consumed little or no maize. A study of 193 new samples from Schild and from sites in the Sny Bottom on the Mississippi River confirms this picture of Schild and demonstrates complex effects of age on isotopic data. High dependence on aquatic protein resources in the Sny Bottom is also likely (Rose 2003). Before isotopic techniques for measuring maize use were available, evidence from dental caries and other aspects of oral health was more important than it is now. Carious lesions in deciduous enamel defects also suggest a gradual increase in maize use (Cook and Buikstra 1979), but there is as yet no comprehensive study of dental caries in these series.

Stature

One puzzle is the failure of maize-using populations to show stature reduction, as might be expected (compare Newman 1962; Bogin and Keep 1999). Kwashiorkor was first discovered in maize-dependent African farmers (Stanton 2001). The failure of either growth in childhood or adult stature to show this expected decline (Cook 1979, 1984) forces us to rethink this problem. Middle Mississippians apparently adopted maize in a varied diet with few of the expected consequences. Their success as measured by their relatively tall

stature suggests that any disadvantages posed by maize as a low-protein staple were offset by its reliability and by the redistributive functions of a chiefdom-level society.

Population Structure

Stature comparisons presuppose genetic homogeneity. Since 1982, several studies have supported the assumption that the series of populations used in the stature studies was regionally continuous. Both Middle Woodland and Mississippian populations are more heterogenous than the intervening Late Woodland groups (Conner 1990; Steadman 2001), perhaps because organization attendant on the two episodes of relative cultural complexity constrained marriage choices. Marriage patterns apparently were largely patrilocal, and biological distances generally reflect geographical and temporal isolation (Konigsberg 1988, 1990a, 1990b). However, sociopolitical boundaries, not simply geographical isolation, are part of the biological distance data from west-central Illinois (Konigsberg 1990a; Konigsberg and Buikstra 1995). An intriguing feature of Konigsberg's work is the idea that a temporal trend is a possible confounding factor (one that Konigsberg removed from his analysis). Temporal trends point to directional selection but may also reflect gene flow from an external source. It is noteworthy that distances between Schild and Yokem sites for both Emergent Mississippian (treated as Late Woodland by other writers) and Mississippian components are quite small, despite their geographical separation, perhaps reflecting the homogenizing effect of contact with the Cahokia polity.

Demographic effects of the maize use are more difficult to tease out, but several studies have been attempted. A principal component analysis that broadly differentiates hunting-and-gathering groups from farming groups places the Schild Late Woodland component between the two Mississippian components at Schild (Buikstra and Konigsberg 1985), despite its relatively low reliance on maize. Maize dependence resulted in increased fertility without the expected increase in childhood mortality (Buikstra et al. 1986) or decrease in age at weaning (Bullington 1991).

Activity-Related Changes

The skeleton responds to habitual activity by increasing resistance to bending forces. An elegant study of cross-sectional geometry has shown that female humeral and femoral strength increased from Middle Woodland to Late Woodland times, possibly as a result of agricultural intensification. Mississippian women exhibit a reduction in strength of the left humerus and forearm, a

result probably linked to mortar-and-pestle technology and to lessened physical requirements in maize processing (Bridges et al. 2000).

Heavy labor investments in small-seed cultivation and silviculture activities (Munson 1984) may be reflected in the contrast between Woodland and Mississippian women. The failure to find significant differences between earlier and later Late Woodland components may reflect the patchwork of investment in maize cultivation that we have seen in the carbon isotope results.

Violence

Many Mississippian and some Late Woodland sites have prominent palisades. Evidence for warfare and interpersonal violence has not yet been fully explored, but there are some intriguing preliminary results. Late Woodland sites have produced many skeletons with embedded projectile points. Schild Late Woodland burials show a high frequency of healed and unhealed head trauma (Heilman et al. 1991; Milner 1995).

Epidemiology

Many of the chapters in *Paleopathology at the Origins of Agriculture* equate periostitis with infection, and many of our colleagues continue to use frequency of periosteal reaction or periostitis as a proxy for morbidity or infection, without sorting out the causes of periosteal new-bone formation (see Armelagos and van Gerven 2003).

But the frequency of periostitis or infection is a misleading index of health for three reasons. First, the diseases that cause bone lesions are chronic. The pathological skeleton represents a survivor, hence a person in relatively good health, compared with the unmarked skeletons of those who succumb rapidly. This aspect of the osteological paradox (Wood et al. 1992) can be overstated, but we must keep in mind that the most common causes of death in premodern contexts—pneumonia and gastrointestinal infections—do not cause bone lesions. Second, the use of bone lesions as an index of health is based on a faulty understanding of bone pathology. Periosteal new-bone formation is not necessarily a consequence of either infection or disease. Metabolic conditions, nutritional deficiencies, trauma, vascular disease, and normal growth and remodeling can cause periosteal new-bone formation (Greenfield 1969). A good counterexample drawn from recent literature in paleopathology is Ortner's focus on scurvy as a probable cause of generalized periosteal reaction in children (Ortner et al. 2001). Many of Ortner's examples come from maize-dependent groups, and deficiency diseases are an expected concomitant of dependence on stored staple foods. Third, minor trauma probably accounts for much peri-

osteal new bone formation in ancient remains, since bruising to bone or to overlying tissue results in subperiosteal bleeding and swelling. The word *inflammation* in medicine refers to swelling, heat, and pain in response to tissue injury. The cause of the injury may be mechanical, thermal, chemical, allergic, or infection. *Inflammation* therefore is not synonymous with *infection,* as suggested in some paleopathological reports. Periostitis is thus a mixed bag that conflates many conditions. Bone lesions are meaningful only when subjected to differential diagnosis. We can see only a few infectious diseases in bone, and these diseases—apart perhaps from dental caries—are not the ones most relevant to food production.

There was once a consensus that tuberculosis was an introduced disease and that Native Americans were uniquely genetically susceptible to TB infection and TB mortality. High TB rates in reservation populations were seen as evidence for a so-called virgin-soil epidemiology, part of a dogma that the New World was once a disease-free eden, isolated from the infected and infectious Old World (see, for example, Hrdlička 1932). The discovery of pre-Columbian TB in Peru and later North America has serious consequences for this dogma, but we have been slow to rethink it.

An exceptionally well preserved Schild Mississippian cemetery had twelve possible cases of TB, a frequency of about 5 percent (Cook 1976, 1980; Buikstra 1976; Buikstra and Cook 1978, 1981). One case (SB 201), a young woman with kyphoscoliosis and psoas abscess, provided a particularly convincing example. But if it was tuberculosis, how could one explain its sudden emergence and surprisingly high frequency?

Apparent virgin-soil epidemics may be an illusion. Hrdlička (1909) documented high TB in the Sioux under prison-camp conditions and low TB among dispersed Navajo pastoralists. Fifty years later, Navajo rates were high (Deuschle 1960) as a result of livestock reductions and crowded housing. Carmichael (1983) has noted that measles behaves differently in small Native American communities than it does in large, continuous populations, and that medical historians need to address the issue of autonomy and synergy of infectious disease. Carey (1965) presents a particularly interesting example from the Arctic. In a year when caribou were abundant and nutrition was excellent, a measles epidemic triggered by infected children returning from boarding school apparently triggered a TB outbreak, resulting in active TB in 55 percent of the children. There were at least 3 chronic cases of TB in the community prior to the outbreak, and one of these adults nursed measles victims; during the outbreak, there were 82 cases of new, active TB in a community of 300. Apparently, measles behaves differently in small Native American communities than in large, continuous populations, suggesting that medical historians

need to address the issue of autonomy and synergy in infectious disease. The virgin-soil event may be fleeting (Carmichael 1983).

Bates (1982) has presented an epidemic wave model for TB susceptibility and resistance that would take decades to cycle between peak and decline, a model that might fit the turn-of-the-century reservation data if the apparent epidemics were snapshots of the peaks.

A simulation study using the Schild data showed that the population would have crashed in twenty to one hundred years, suggesting that the disease in question was not TB (McGrath (1988). But this is a misinterpretation of a regional picture that has since emerged. Its high frequency is a biased estimate of regional frequencies.

Evidence in other contemporary sites (Milner 1992; Hanson and Steadman 2001) supports far lower frequency estimates. Three comparable sites each have a single plausible tuberculosis case. A regional—as opposed to single-site—estimate of prevalence would not present the statistical problem McGrath identified. She argued from a focal example (or cluster) to a regional population process. Nevertheless, the lower Illinois Valley did become depopulated after 1200 AD, and perhaps the simulation shows us why.

In the 1980s, we could not rule out blastomycosis, a soil fungus endemic to the Midwest, as a cause of the lesions at Schild. Blastomycosis is an occupational disease of farmers and was very likely linked to Mississippian maize cultivation. However, polymerase chain reaction and its application to ancient biomolecules has now shown that the individual (SB201) with the psoas abscess did indeed suffer from tuberculosis (Braun et al. 1998). Raff and colleagues (n.d.) have found tuberculosis DNA in apparently healthy ribs from five individuals with nonspecific rib lesions as well as TB lesions elsewhere in the skeleton, and from two others with TB lesions elsewhere.

The Individual in Prehistory

It is interesting to note that SB201, who was Perino's poster girl for Late Woodland to Mississippian acculturation, was exhibited for many years as a flexed burial—that is to say, Late Woodland—although she was buried in a Mississippian cemetery with a Mississippian jar. Genetic distance studies have shown that she was like her neighbors. Her burial position was a consequence of her tuberculosis and flexion contractions. Her diet was as high in maize as that of her neighbors (Rose 2003: 153; Schober 1998). It is not strikingly higher, as one might have expected in an invalid!

Larger Contexts

One issue that puzzles me concerning the *Paleopathology at the Origins of Agriculture* volume (Cohen and Armelagos 1984) is the infrequency with which the book's chapters have been cited by archaeologists who are not also physical anthropologists. Perhaps the answer lies in the disparate histories of the two fields. Interest in skeletons as evidence for adaptation coincided with the emphasis on ecological and processual models that characterized the "New Archaeology." *Paleopathology at the Origins of Agriculture* served as a high-water mark for interaction among disciplines in this era, but the New Archaeology was getting old by 1984. Unfortunately, as archaeologists have moved to new theoretical issues, the work of paleopathologists has become less relevant to their interests.

The Backbone of History project (Steckel and Rose 2002) is a revitalization of this topic in a new context that derives its rigor and scope from econometrics and economic history. Unfortunately, within this field, stature is seen as a proxy for adaptation, with lesser contributions from other information that one can derive from the skeleton, a view that oversimplifies a complex problem and compounds the misjudgment with an oversimplified concept of infectious disease. An example is Steckel and Prince's (2001) use of stature data to show that historic Plains populations were uniquely healthy and advantaged. The scarcity of evidence for bone lesions in equestrian-period Plains series emphasizes the problems of using periosteal lesions to measure infection, given the abundant historical evidence for devastating epidemics (Owsley 1992). The explanatory power of the Backbone of History project comes at the cost of verisimilitude in explaining individual cases.

Traditional subsistence systems may be highly buffered against environmental perturbations, possibly explaining the minimal effects of maize in the Midwest. Caution in oversimplifying ancient systems is dictated when the great Pueblo abandonment, an ecological crisis that surely resulted in increased mortality owing to infectious disease in the malnourished, is largely invisible in paleodemographic and paleopathological data (Nelson et al. 1994). The same small-seed genera that were the backbone of horticulture in the Midwest were the foods to which the Zuni resorted when maize crops failed (Cushing 1920). We cannot know whether archaeobotanical or isotope fractionation data reflect a diet that is stable or fluctuating from year to year.

Archaeologists have moved away from the theoretical constraints of the New Archaeology because these are seen as reductionist. In thinking about diet and health, I believe that we need to reemphasize the particular and contingent aspects of local and regional contexts if we are to make our work meaningful as anthropology.

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2

Health and Lifestyle in Georgia and Florida

Agricultural Origins and Intensification in Regional Perspective

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Some 1,300 miles of coastline on the Atlantic Ocean and Gulf of Mexico dominate the ecology of modern-day Georgia and Florida, providing earlier foragers and later farmers with a remarkable variety of marine resources, including fish and shellfish along with terrestrial animals and plants. Terrestrial resources in the interior are similar to those of the coast.

We describe two major transitions: the advent of maize agriculture and the influence of European contact. For purposes of comparison, we divide the skeletal series into early and late prehistoric and early and late contact periods. Prehistorically, cultural and social development in most of the area was part of the post–1000 BP, pan-Mississippian florescence (see, for example, Hally 1994; Hally and Rudolph 1986; Hally and Langford 1988; Bense 1994; King 2003) and was linked closely with the adoption of maize farming.

The Skeletal Record in Georgia and Florida

The results discussed in this chapter combine published studies and new data. We focus on three regions: (1) Atlantic coastal Georgia and Florida, colonized by Spain; (2) upland Georgia; and (3) central and southern Florida.

Data for the populations of region 1 (the prehistoric and historic-era Guale) are relatively complete. The record is also robust for northern Florida, for the region of the panhandle occupied by the Apalachee, and for the eastern panhandle and the northeast portion of the peninsula occupied by the Timucua. For purposes of analysis, we subdivide region 1 samples into seven groups: coastal Georgia early prehistoric (2400–1000 BP), Florida early prehistoric (2000–1000 BP), coastal Georgia late prehistoric (1000 BP–AD 1550), Florida

Table 2.1. Skeletal Samples from Georgia and Florida

Subregion/Group/Site	Location	Cultural Association
Subregion 1: Coastal Georgia, Coastal Plain (Inland) Georgia, and Northern Florida		
Georgia Early Prehistoric (2400–1000 BP)		
Deptford site	inland Georgia	Guale
Indian Kings Tomb	inland Georgia	Guale
Cedar Grove Mound A	inland Georgia	Guale
Cedar Grove Mound B	inland Georgia	Guale
Cedar Grove Mound C	inland Georgia	Guale
Walthour (CH 11)	coastal Georgia	Guale
McLeod Mound	coastal Georgia	Guale
Seaside Mound I	coastal Georgia	Guale
Seaside Mound II	coastal Georgia	Guale
Cunningham Mound C	coastal Georgia	Guale
Cunningham Mound D	coastal Georgia	Guale
Cunningham Mound E	coastal Georgia	Guale
South New Ground Mound	coastal Georgia	Guale
Evelyn Plantation	inland Georgia	Guale
Sea Island Mound	coastal Georgia	Guale/Mocama
Airport site	coastal Georgia	Guale/Mocama
Cannons Point	coastal Georgia	Guale/Mocama
Charlie King Mound	coastal Georgia	Guale/Mocama
Florida Early Prehistoric (AD 0–1000)		
Nichols	coastal Florida	Apalachee
Melton Mounds	inland Florida	Timucua
McKeithen Mounds	inland Florida	Timucua
Cross Creek Mound	inland Florida	Timucua
Wacahoota Mound	inland Florida	Timucua
Henderson Mound	inland Florida	Timucua
Mayport Mound	coastal Florida	Timucua
Georgia Late Prehistoric (AD 1000–1550)		
Irene Burial Mound	inland Georgia	Guale
Irene Large Mound	inland Georgia	Guale
Irene Mortuary	inland Georgia	Guale
Deptford Mound	inland Georgia	Guale
Red Knoll	inland Georgia	Guale
Skidaway Mitigation 3	coastal Georgia	Guale
Groves Creek	coastal Georgia	Guale
Johns Mound	coastal Georgia	Guale
Marys Mound	coastal Georgia	Guale
Southend Mound I	coastal Georgia	Guale
Southend Mound II	coastal Georgia	Guale
North End Mound	coastal Georgia	Guale/Mocama
Low Mound, Shell Bluff	coastal Georgia	Guale/Mocama
Townsend Mound	coastal Georgia	Guale
Norman Mound	coastal Georgia	Guale
Lewis Creek	inland Georgia	Guale/Mocama
Seven Mile Bend	inland Georgia	Guale
Little Pine Island	coastal Georgia	Guale
Red Bird Creek	coastal Georgia	Guale/Mocama
Oatland Mound	coastal Georgia	Guale/Mocama

continued

Table 2.1.—*Continued*

Subregion/Group/Site	Location	Cultural Association
Kent Mound	coastal Georgia	Guale/Mocama
Martinez Test B	coastal Georgia	Guale/Mocama
Indian Field	coastal Georgia	Guale/Mocama
Taylor Mound	coastal Georgia	Guale/Mocama
Couper Field	coastal Georgia	Guale/Mocama
Florida Late Prehistoric (AD 1200–1500)		
Lake Jackson	inland Florida	Apalachee
Waddell's Mill Pond	inland Florida	Apalachee
Leslie Mound	inland Florida	Timucua
Goodman Mound	coastal Florida	Timucua
Browne Mound	coastal Florida	Timucua
Holy Spirit Church	coastal Florida	Timucua
Georgia Early Mission (AD 1600–1680)		
Pine Harbor	coastal Georgia	Guale
Santa Catalina de Guale	coastal Georgia	Guale
Florida Early Mission (AD 1600–1680)		
Ossuary at Santa Catalina	coastal Florida	Timucua
Santa Maria de Yamasee	coastal Florida	Yamasee
San Martín de Timucua	inland Florida	Timucua
San Pedro de Patale	inland Florida	Apalachee
Snow Beach	coastal Florida	Apalachee
Florida Late Mission (AD 1680–1700)		
San Luis de Apalachee	inland Florida	Apalachee
Santa Catalina de Amelia	coastal Florida	Guale
Subregion 2: Upland Georgia		
Upland Georgia Late Prehistoric (AD 1200–1540)		
Etowah	upland Georgia	Creek
Leake	upland Georgia	Creek
Stamp Creek	upland Georgia	Creek
King	upland Georgia	Creek
Baxter	upland Georgia	Creek
Sixtoe	upland Georgia	Creek
Bell Field	upland Georgia	Creek
Little Egypt	upland Georgia	Creek
Pott's Track	upland Georgia	Creek
Chauga	upland Georgia	Creek
Draw Bridge	upland Georgia	Creek
Shinholser	upland Georgia	Creek
Long Swamp	upland Georgia	Creek
Wilbanks	upland Georgia	Creek
Dyar	upland Georgia	Creek
Cold Springs	upland Georgia	Creek
Ogeltree	upland Georgia	Creek
Shaky Pot	upland Georgia	Creek
Tugalo	upland Georgia	Creek
Park	upland Georgia	Creek
Avery	upland Georgia	Creek

continued

Table 2.1.—*Continued*

Subregion/Group/Site	Location	Cultural Association
Subregion 3: Central and Southern Florida		
Florida Early Prehistoric (pre-AD 1000)		
Buck Key	coastal Florida	Calusa
Casey Key	coastal Florida	Calusa
Galt Island	coastal Florida	Calusa
Horr's Island	coastal Florida	Calusa
Palmer	coastal Florida	Manasota
Perico Island	coastal Florida	Manasota
Pine Island	coastal Florida	Calusa
Useppa Island	coastal Florida	Calusa
Florida Late Prehistoric (AD 1000–1600)		
Aqui Esta	coastal Florida	Manasota
Horr's Island (Blue Hill Mound)	coastal Florida	Calusa
Safety Harbor	coastal Florida	Safety Harbor
Tatham Mound	inland Florida	Safety Harbor
Tierra Verde	coastal Florida	Safety Harbor
Weeki Watchee	coastal Florida	Safety Harbor

late prehistoric (1000 BP–AD 1500), Georgia early mission (AD 1600–1680), Florida early mission (AD 1600–1680), and Florida late mission (AD 1680–1700). Data are derived from nearly all archaeological sites (Larsen 1982; Larsen and Griffin et al. 2001; Larsen et al. 2002).

Region 2 (interior upland Georgia) is represented by late prehistoric and early contact period agriculturalists circa 800 BP through AD 1540. This region, unlike the coastal area, was not missionized and thus did not experience an agricultural intensification (Williamson 1998, 2000).

Region 3 comprises central and southern peninsular Florida with late prehistoric and contact period foragers. Most data for region 3 are from the Gulf coast (Hutchinson 2004).

Region 1: Coastal Georgia and Northern Florida

DIET AND TOOTH USE

Stable isotope variation

Carbon and nitrogen stable isotope ratios show clear subregional variation (Hutchinson et al. 1998; Larsen and Hutchinson et al. 2001). Before 1000 BP, there is a uniform pattern of relatively negative $\delta^{13}C$ values and positive $\delta^{15}N$ values, reflecting diets based on wild plants and animals and, for coastal populations, significant marine diets. After 1000 BP, however, regional differences in isotopic signatures begin to emerge. In coastal Georgia and the western

panhandle of Florida, there is a general trend toward less negative $\delta^{13}C$ values and some reduction in $\delta^{15}N$ values, representing the adoption of maize and a decline in marine foods.

After contact, the picture changes. In the Guale missions of coastal Georgia (and, later, northern Florida), the appearance of less negative $\delta^{13}C$ values and less positive $\delta^{15}N$ values compared to earlier populations in the same region suggests an increased commitment to maize and a further decline in the use of marine foods.

All Florida mission populations adopted a maize-based diet. The nonmission samples from the Snow Beach site on coastal panhandle Florida dating to the seventeenth century AD show a maize signature, albeit with a significant marine component (Magoon et al. 2001). The convergence in diet across the region, as expressed in stable isotope values, indicates the impact of colonization and the mission systems. Populations that had been foragers adopted agriculture, and farmers intensified their commitment to agriculture. However, the adoption of agriculture occurred later in northern Florida than in coastal and interior Georgia.

Dental microwear

Occlusal microwear on maxillary central incisors and first molars of prehistoric and contact-era populations reveals several trends (Teaford 1991; Teaford et al. 2001). First, populations living inland, regardless of time or location, have more and smaller microwear features (pits and scratches) than populations living on the Atlantic coast, primarily reflecting soil composition (sandy on the coast, clay in the interior). Second, microwear on molars is more homogeneous prehistorically than in the historic period groups, probably as a result of a shift in food preparation (Teaford et al. 2001). Alternatively, the greater heterogeneity of features in the historic period (such as variable scratch orientation) might reflect the shift to some type of maize-based amorphous mush. In this case, the homogeneous orientation of scratches in the prehistoric molars probably reflects the need for more precise occlusion for chewing foods tougher than those of later periods.

HEALTH AND STRESS

Dental caries

Dental caries provides complementary evidence for the dietary transition. For maize agriculturalists, dental caries is a sensitive indicator of carbohydrate consumption. Prior to 1000 BP, caries frequency (in terms of the percentage of teeth affected) throughout the region is about 1 percent (Table 2.2). Only in the Apalachee area are dental caries common. All other Florida sites display

Table 2.2. Dental Caries in Coastal Georgia and Northern Florida

	Total[a]		Female		Male	
Region/Group	%	(*n*)	%	(*n*)	%	(*n*)
Georgia Early Prehistoric	1.2	(2,479)	1.1	(1,034)	0.3	(638)
Florida Early Prehistoric	0.8	(854)	9.1	(22)	7.3	(41)
Georgia Late Prehistoric	9.6	(5,984)	12.8	(2,405)	8.3	(1,931)
Florida Late Prehistoric	1.3	(866)	6.0	(50)	4.2	(119)
Georgia Early Mission	7.6	(4,466)	11.0	(598)	14.9	(441)
Florida Early Mission	7.4	(2,162)	8.3	(542)	4.4	(568)
Florida Late Mission	24.4	(2,378)	21.1	(606)	21.4	(754)

[a] Juveniles and unsexed and sexed adults.

no carious lesions. The Georgia coastal region shows a significant increase in dental caries after 1000 BP. In both Florida and Georgia, caries are common in the early mission period. A great deal of variation in caries frequency evidently existed during the late mission period (a low of 4.6 percent at San Luis de Apalachee to a high of 34.2 percent at Santa Catalina de Amelia).

Porotic hyperostosis and cribra orbitalia

All prehistoric sites in coastal Georgia and northern Florida display a low prevalence of porotic hyperostosis and cribra orbitalia (Table 2.3). In coastal Georgia, agriculture brought no change. In contrast, the frequency of PH and CO increased in postcontact mission groups in both areas. In this setting, the probable cause is iron-deficiency anemia (Schultz, Larsen, and Kreutz 2001). The shift in diet may have been a factor. Common to all settings in the contact period was an increased commitment to agriculture and a decline in the range of foods eaten. On the coast, there was a reduction in the consumption of marine food. However, the lack of increase in pathology with the appearance of maize agriculture in coastal Georgia suggests a more complex picture.

Table 2.3. Porotic Hyperostosis for Individuals in Coastal Georgia and Northern Florida

	Total[a]		Juvenile[b]		Female		Male	
Region/Group	%	(*n*)	%	(*n*)	%	(*n*)	%	(*n*)
Georgia Early Prehistoric	0.0	(113)	0.0	(13)	0.0	(42)	0.0	(35)
Florida Early Prehistoric	0.0	(12)	0.0	(0)	0.0	(2)	0.0	(8)
Georgia Late Prehistoric	3.3	(308)	0.0	(33)	2.4	(123)	5.7	(88)
Florida Late Prehistoric	0.0	(13)	0.0	(0)	0.0	(2)	0.0	(6)
Georgia Early Mission	9.4	(32)	0.0	(5)	15.4	(13)	8.3	(12)
Florida Early Mission	28.4	(102)	23.1	(13)	15.0	(20)	31.3	(16)
Florida Late Mission	21.1	(90)	50.0	(18)	11.4	(35)	11.4	(35)

[a] Juveniles and unsexed and sexed adults.

[b] Individuals less than 10 years of age.

Table 2.4. Periosteal Reactions for Tibiae for Coastal Georgia and Northern Florida

	Total[a]		Female		Male	
Region/Group	%	(*n*)	%	(*n*)	%	(*n*)
Georgia Early Prehistoric	9.5	(126)	4.3	(47)	9.3	(32)
Florida Early Prehistoric	30.0	(20)	100.0	(2)	0.0	(2)
Georgia Late Prehistoric	19.8	(331)	24.1	(133)	23.6	(93)
Florida Late Prehistoric	37.9	(29)	37.5	(8)	27.3	(11)
Georgia Early Mission	15.4	(36)	14.3	(7)	23.1	(13)
Florida Early Mission	16.1	(236)	16.7	(36)	17.4	(46)
Florida Late Mission	59.3	(96)	65.7	(35)	70.0	(36)

[a] Juveniles and unsexed and sexed adults.

Infectious disease

Analysis of periosteal reactions shows clear patterns of variation (Table 2.4). In Georgia, there is an increase in these lesions, from about 10 percent to 20 percent of tibiae from foragers to farmers. In Florida, there are much higher frequencies—30 percent and 38 percent—in the early and late prehistoric groups, indicating that something other than agriculture may explain the high levels of infection. Most of the lesions are localized, but some individuals have treponemal lesions.

In the Georgia and Florida early mission samples, the frequencies are also relatively high, although not as high as in the late prehistoric period. The highest frequency is in the Santa Catalina population on Amelia Island (nearly 60 percent). Our overall impression is that infection, nonspecific and specific, is much more prevalent in the Florida portion of this region.

Enamel defects (hypoplasias and Wilson bands)

Several trends emerge from the comparison of frequency and width of enamel hypoplasias (Hutchinson and Larsen 2001; Simpson 2001). Georgia populations have generally a higher frequency of defects per tooth than Florida populations, suggesting regional variation in physiological stress perhaps related to the earlier development of agriculture in Georgia than in Florida. In contrast, the frequency of enamel hypoplasias per individual is greater in Florida than in Georgia. Thus, broadly speaking, fewer individuals are affected in Georgia than Florida, but the individuals that are affected in Georgia exhibit more stress episodes than those in Florida. In temporal perspective, enamel defects do not increase in frequency. Rather, there is a decline in the number of individuals affected or only slight increases for the adoption of agriculture during the mission era in Florida. However, in both Georgia and Florida, the late mission period shows a sharp rise in the number of individuals affected, reflecting declining health, of which agricultural intensification was likely one factor.

Table 2.5. D_{30+}/D_{5+} Fertility Ratio for Coastal Georgia and Northern Florida

Region/Group	D_{30+}	D_{5+}	D_{30+}/D_{5+}
Georgia Early Prehistoric	58	153	.3790
Florida Early Prehistoric	23	75	.3067
Georgia Late Prehistoric	98	280	.3500
Florida Late Prehistoric	29	47	.6170
Georgia Early Mission	83	294	.2823
Florida Early Mission	65	193	.3368
Florida Late Mission	94	190	.4947

Frequency changes in Wilson bands (accentuated striae of Retzius) show a rise in the percentage of individuals affected by stress when the preagricultural late prehistoric populations are compared to the agricultural mission samples in Florida (Simpson 2001), reflecting the impact of dietary change and general deterioration of health.

DEMOGRAPHY AND THE DIETARY TRANSITION

The ratio of D_{30+}/D_{5+}, a general indicator of population growth and fertility (Buikstra et al. 1986), reveals evidence of demographic change (Table 2.5). The Georgia early and late prehistoric, Florida early prehistoric, Georgia early mission, and Florida early mission values fall within a relatively narrow range of .2823 to .3790. The differences among these five groups are not statistically significant. The other two groups are quite different, however. The ratio is relatively high in the Florida late prehistoric (.6170), but that reflects a probable sample bias—only two samples are represented, the number of individuals is small, and the samples are dominated by older adults. The seventh sample, the Florida late mission series, has a relatively high ratio. This sample comprises two sites, with a relatively low ratio for San Luis de Apalachee (.2632) and a very high ratio for Santa Catalina on Amelia Island (.7263). We regard the high ratio as reflecting a very low birth rate in a stressed setting involving relatively more disease and population disruption at the end of the mission era. We interpret the low ratio (reflecting a relatively large number of juveniles and small number of older adults) as indicating a highly viable population, consuming plant domesticates but also a significant amount of animal foods including cattle. The zooarchaeological and historical evidence indicates a significant presence of meat in the diets of the San Luis inhabitants (Reitz 1993). The low caries prevalence is consistent with this conclusion. Unfortunately, only one individual had sufficiently preserved collagen for stable isotope analysis. But that person had relatively negative $\delta^{13}C$ values, consistent with a diet involving low maize consumption.

ACTIVITY AND LIFESTYLE

With the shift to agriculture, a decline in osteoarthritis is evident, followed by a marked increase in the (Guale) mission population from Amelia Island (Larsen and Ruff 1994; Larsen et al. 1996; Larsen 1998).

Analysis of cross-sectional geometric properties parallels the osteoarthritis results. Like osteoarthritis, bone strength (J, which measures overall loading of the bone) and workload decline among early Georgia agriculturalists (Ruff and Larsen 2001). There is no evidence of body size differences (based on femur and humerus length). The overall similarity of the series in Georgia and Florida indicates that the changes in bone strength are real and not influenced by body size (see Ruff and Larsen 2001).

During the early mission period, bone strength increased in the Georgia population, albeit not to the level of the prehistoric foragers. Agricultural intensification, related to the Spanish demand for labor, increased the workload. The mission-era bone strength measures are generally higher than the Georgia late prehistoric samples.

SEX DIFFERENCES IN HEALTH AND LIFESTYLE IN COASTAL GEORGIA AND NORTHERN FLORIDA

The prevalence of dental caries, periosteal reactions, and osteoarthritis among males and females provides insight into patterns of health and lifestyle in the adoption and intensification of agriculture. First, for nearly all groups, carious lesions are more prevalent in females than in males (Table 2.2), suggesting that females were consuming greater amounts of carbohydrates, except in early mission period coastal Georgia samples (Santa Catalina de Guale). The latter may simply reflect small samples. Second, tibial periosteal reactions show a mixed picture of female-male differences (Table 2.4). Generally, males have somewhat greater frequencies for the prehistoric and historic-era Guale (coastal Georgia and Santa Catalina, Amelia Island; Larsen 1998). In non-Guale Florida samples, the differences are not significant. Finally, osteoarthritis is almost universally higher in adult males than in females.

Cross-sectional geometric properties of bones add insight into patterns of workload of men and women. In femur values of J, representing overall loading, there is a steady decline in sexual dimorphism, the biggest drop occurring in the foraging to farming transition in coastal Georgia, suggesting a decline in activity differences between men and women. The least dimorphism occurs in the latest Guale series (Santa Catalina, Amelia Island), indicating that activities involving the legs (walking and running) were virtually identical. We believe that these data reflect involvement of both men and women in agriculture in Spanish mission settings.

Region 2: Upland Georgia

This region was explored by Spaniards but was not colonized or missionized. Unlike the coastal zone, this region did not see an intensification of agriculture with contact. Skeletal remains from this area are all late prehistoric agriculturalists and early contact period peoples.

HEALTH AND STRESS

Patterns of health and disease between circa 800 BP and 1540 AD are described by Williamson (1998, 2000).

Dental caries

These upland groups display high frequencies of caries (9.9 percent), almost certainly reflecting maize agriculture. This frequency is considerably higher than the single early prehistoric sample from Stallings Island (3.9 percent) (Wilson 1997).

Infectious disease

Frequencies of periosteal reactions (13.0 percent of tibiae) in the Georgia uplands are intermediate between those of early and late prehistoric Georgia coastal groups. Several individuals in the Georgia upland samples have tibiae that show extensive remodeling and bowing, indicating the presence of treponematosis in late prehistory (Blakely 1980; Williamson 1998).

Porotic hyperostosis and cribra orbitalia

The Georgia upland samples reveal a low prevalence of porotic hyperostosis and cribra orbitalia, 4 percent (Williamson 1998, 2000) although this is slightly higher than at Etowah in northwestern Georgia (3.2 percent of 125, as reported by Blakely 1980) and the contemporary coastal samples. Apparently, iron-deficiency anemia was not common in upland or coastal Georgia.

Enamel defects

Hypoplasias are common in the Georgia uplands and show similar frequencies in the two regions (Williamson 1998, 2000), suggesting a common stress experience.

Osteoarthritis

Frequency of degeneration of articular joints (particularly the vertebral joints) in the Georgia uplands is generally greater than in the contemporary Georgia coastal populations (Williamson 2000). These differences, controlling for age, suggest that the upland populations experienced greater mechanical demand

than coastal populations. Although specific differences in lifestyle are not clear, the data suggest that upland terrain provides the greater mechanical challenge, perhaps related to carrying loads up and down hilly terrain. These differences are consistent with the finding of greater cross-sectional geometric values in uplands than in flatlands in North America generally (Larsen et al. 1995; Ruff 1999; Williamson 1998, 2000), suggesting a common stress experience.

SEX DIFFERENCES IN HEALTH AND LIFESTYLE IN UPLAND GEORGIA

Comparison of sex differences in dental caries, periosteal reactions, and osteoarthritis in late prehistoric upland Georgia shows a pattern similar to that of late prehistoric coastal Georgia (Williamson 1998, 2000). Caries is significantly more common in females than in males, whereas periosteal reactions do not vary by sex. As in coastal Georgia, males have more osteoarthritis than females do.

In summary, the late prehistoric Georgia upland populations show health profiles (other than arthritis) similar to those from coastal Georgia of the same period.

Region 3: Central and Southern Florida

For virtually all of peninsular Florida, the increasing social complexity that characterizes the rest of the region was minimal or nonexistent. The skeletal samples are all from the very late prehistoric and contact period. Stable isotope analysis indicates that with the exception of the western and central panhandle region, native populations in the area north of Tampa Bay in Florida exploited wild plants and animals exclusively until the postcontact period, when they became partly agricultural. Southern populations (for example, Calusa and Manasota) relied on foraging for food throughout the entire record, never acquiring agriculture before or after European contact.

Evidence of health, lifestyle, and diet were limited until the last few years (Hutchinson 2004). The most comprehensively studied bioarchaeological record from peninsular Florida is from the Gulf coast (Hutchinson 2004).

DIET AND TOOTH USE

Stable isotope variation

Analyses of collagen and apatite carbonate for carbon and collagen for nitrogen show consistent regional dietary preferences (Hutchinson 2004). For coastal populations, $\delta^{13}C$ values from collagen are extremely positive and very different from those noted for the Atlantic coast (region 1) discussed above.

There were no C_4 plants in the diet. The signatures are attributable to consumption of predominantly marine resources. The $\delta^{13}C_{ca\text{-}co}$ values indicate a diet focused on marine resources with some terrestrial dietary items but not C_4 domesticated grasses (maize). Positive nitrogen values suggest intensive exploitation of marine species.

Individuals from the precontact stratum at Tatham Mound, on the interior freshwater Withlacoochee River on the Florida Gulf coast, have dietary signatures consistent with exploitation of freshwater fish and other lacustrine/riverine species, some terrestrial species, and limited or no C_4 grasses. Individuals from the contact-era stratum at Tatham Mound show a slight shift toward more positive carbon values, indicating the possible incorporation of some maize. Nitrogen values are consistent with the exploitation of freshwater species and terrestrial species.

Tooth microwear

Microwear on the occlusal surfaces of molars from the Palmer population shows many trends similar to those of region 1 above (Hutchinson 2004). The Palmer population shows the same wide scratches and deep pits as Atlantic coastal populations from Georgia, Florida, and North Carolina, probably reflecting the incorporation of sand with marine foods.

HEALTH AND STRESS

Dental caries

Carious lesions are infrequent in coastal populations in region 3, averaging only 1 percent of teeth affected (Hutchinson 2004). The precontact interior population from Tatham Mound has caries affecting 2 percent of teeth from precontact individuals and 4 percent of teeth from the contact period. The percentage of individuals affected by carious lesions presents a somewhat different comparison. Prior to 1000 BP, an average of 4 percent of adults have carious lesions, while 9 percent of individuals after 1000 BP are affected. The higher caries frequency in the interior contact period Tatham Mound sample and the stable isotope results (a slight positive increase in carbon values) both suggest the addition of maize agriculture after contact.

Porotic hyperostosis and cribra orbitalia

In this region, PH is common, ranging generally from 29 percent to 44 percent of individuals (Hutchinson 2004). Three populations—Tatham Mound precontact, Tatham Mound contact, and Weeki Watchee—have lower frequencies (1–11 percent) after 1000 BP that are more comparable with the populations of regions 1 and 2. A variety of circumstances can cause these lesions. Given

the absence of maize as indicated by stable isotope analysis, we believe that a probable cause was intestinal parasitic infection from undercooked seafood.

Infectious disease

Proliferative responses (periosteal reactions and osteomyelitis) appear to increase from 6 percent in the Palmer sample to an average of 16 percent of individuals affected after 1000 BP (Hutchinson 2004). Higher frequencies have been reported prior to 1000 BP, however, at Manasota Key (18 percent; Dickel 1991). Many of the responses are localized, but many are extreme, completely altering portions of most of the bones affected. Medullary closure of long and short bones occurs in some cases. Stellate scarring of crania is common, suggesting the presence of treponemal infections. Hutchinson and coworkers (2005) have found that 2 percent of individuals from region 1 in prehistoric and protohistoric Florida had treponemal infections, suggesting that region 3 may have experienced relatively higher rates of treponematosis than region 1.

Enamel defects (hypoplasias)

There is no clear temporal trend for EH in this region (Hutchinson 2004). The prevalence appears to be somewhat lower for some populations after 1000 BP, but the range extends from 23 percent to 75 percent of individuals affected. The frequency of affected individuals increased following European contact, with Tatham Mound and Weeki Wachee populations exhibiting the two highest frequencies (57 percent and 75 percent, respectively) of the post–1000 BP groups, suggesting that the increase in physiological stress after contact came not only from agriculture but also from newly introduced stresses such as Old World diseases.

Activity and lifestyle (osteoarthritis)

Osteoarthritis appears to be highest for the Palmer population prior to 1000 BP (Hutchinson 2004). Of the Palmer adults, 11 percent experienced osteoarthritis, as compared with the 4 percent of Tierra Verde and Tatham Mound populations, both living after 1000 BP. These differences may indicate the mechanical demand of the foraging life of the Palmer individuals, although stable isotope results indicate no difference in the diet between those living at Palmer and the coastal people of Tierra Verde.

Sex differences in health and lifestyle in central and southern Florida

Adult males and females show important differences in the frequency of caries, porotic hyperostosis, and enamel hypoplasia. Males tend to have more carious lesions than females do, unlike the pattern observed in regions 1 and

2. Males also have higher frequencies of PH and EH than females do. A possible explanation could be differences in diet, but stable isotope signatures do not fully support this interpretation. Carbon signatures for the Palmer and Tatham Mound skeletons, the two largest skeletal samples examined, are not significantly different. However, both populations show elevated nitrogen signatures for males as compared to females. Gender differences in proliferative lesions show no pattern.

In summary, populations that inhabited region 3 (peninsular Florida) prior to contact did not adopt maize agriculture, and their commitment to agriculture after the arrival of Europeans was relatively minor compared to that of coastal Georgia and northern Florida. For much of the peninsula, populations showed heavy reliance on marine foods. The peninsular Florida populations (as viewed from the Gulf coast) did not appear to experience the same increase in frequency of pathology as those that adopted agriculture. However, the common occurrence of treponemal infections and porotic hyperostosis indicates that these groups were not disease-free. The presence of treponemal infections resulted from life in tropical settings, where the pathogen thrives (Powell and Cook 2005).

Summary of Georgia and Florida

We have reviewed indicators of prehistoric and early historic-era health and lifestyle in the modern states of Georgia and Florida. In coastal Georgia and northern Florida, maize agriculture was introduced sometime around 1000 BP, accompanied by evidence for declining health that includes increased dental caries and periosteal reactions. Following the arrival of Europeans and the establishment of missions in the late sixteenth century, further declines in health are documented, involving an increase in PH and EH. Increased morbidity likely reflects an increased focus on agriculture and the arrival of Europeans, introducing new pathogens and other new problems. We believe that declining nutritional quality after contact was the leading factor in declining health. Both osteoarthritis and biomechanical analyses document a probable decline in workload with the transition to agriculture prior to contact, but with missionization, this trend reversed, reflecting labor exploitation. Region 2 shows a general pattern of health similar to the late prehistoric populations of region 1, including relatively high levels of infection.

Central and southern peninsular Florida (region 3) saw different temporal patterns in health and activity in comparison with regions 1 and 2, largely explained by the absence of agriculture. There has been some suggestion that maize agriculture was present in at least one prehistoric setting in southern peninsular Florida, at the Fort Center site in the south-central peninsula circa

1500–1000 BP (Sears 1982). If maize agriculture was practiced in this area of Florida, it was unique and short-lived (Milanich 1994). However, the prevalence of pathological conditions is quite low (2.7 percent of teeth are carious; 1.8 percent of bones have periosteal reactions; and 2.5 percent exhibit porotic hyperostosis; see Miller-Shaivitz and Iscan 1991).

The highest prevalence of pathological conditions in peninsular Florida tends to occur in later prehistoric contexts when population size was highest. This suggests that population size (and degree of sedentism) were highly influential in determining quality of life and health among these populations. This is also a pattern that emerges in late Archaic upland Georgia groups living prior to the adoption of maize agriculture. That is, in the late Archaic Stallings Island samples, there are elevated levels of porotic hyperostosis and periosteal reactions (Wilson 1997), higher than in earlier samples and similar to the levels found among agricultural groups in late prehistory. For example, 26.3 percent (10/38) of crania have porotic hyperostosis (Wilson 1997). This pattern of elevated morbidity appears to be associated with a period of earlier prehistory when foraging groups lived a somewhat more sedentary lifestyle, concomitant with an increase in population size. The groups were clearly not agricultural, an assumption supported by relatively low dental caries prevalence (3.9 percent of teeth affected).

In conclusion, isotopic evidence indicates that the Georgia and Florida region experienced a shift from foraging to farming. This dietary transition was accompanied by a decline in health and an alteration in lifestyle. The change in health was the result of both dietary change and nutritional decline, indirectly related to population size and density. Whenever population increased, whether in upland Georgia in early prehistory or in coastal Georgia and Gulf coast Florida in later prehistory, skeletal morbidity increased. Agriculture played a direct—but not exclusive role—in explaining the changes in health and lifestyle that we document in this chapter.

Acknowledgments

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3

A Brief Continental View from Windover

GLEN H. DORAN

The Windover site (8BR246) was discovered in 1982 during road construction (Doran 2002a, 2000b). The developer contacted Florida State University, and anthropology department faculty (R. C. Dailey and Doran) visited the site and began developing a research design for excavation and analysis. Excavation began in the fall of 1984 and continued each fall through 1986. In this analysis, information from Windover and from a series of other databases will be used to examine site and skeletal sample distributions on a continental basis. Health will be considered, using femur length as one proxy, along with fracture incidence, cribra orbitalia, and porotic hyperostosis rates (also examined on a broad continental chronological basis).

Although every archaeological site can provide useful information, some clearly are potentially more informative than others. Windover represents an unusual form of "aquatic" burial practice seen only in central and southern Florida and in a very restricted time interval, roughly 8000–6000 BP (uncorrected).

Windover is firmly in the hunting-gathering-fishing tradition, which proved to be a durable and effective tradition in much of southern Florida until contact. Seasonal fluctuations in that region, in contrast to many other areas, are relatively minor, and terrestrial and freshwater resources are abundant and diverse. The region is today considered to be humid subtropical, though it was drier and cooler some 7,000 years ago (Holloway 2002). Ecologically, Windover is positioned on the western margin of the Atlantic Coastal Ridge (ACR), a slightly elevated ridge (normally only a few meters above sea level) running parallel to the Atlantic coast (White 1970). The western boundary of much of the ACR is the northward-flowing St. Johns River, which has its headwaters just south of Windover. The eastern margin of the ACR in this region is the Indian River (actually an estuary system with links to the Atlantic Ocean and relatively minor freshwater inputs from the mainland). West of the ACR lies the St. Johns River valley and an upland area on the western shores of the St. Johns. This area is best defined as an extensive network of streams, creeks, ponds, lakes, and marshes—many of which show dramatic seasonal variability related to fluctuations in rainfall. The result is a complex mosaic of linearly distributed resources paralleling the coast. Essentially, all resources of the region

can be obtained within a twenty-kilometer span. Windover is within a fifteen-minute walk of the St. Johns, and all the resources exploited by the Windover people appear to lie west of the site in the St. Johns basin and along the upland marsh mosaic.

Within the site, 168 individuals were recovered and roughly half of the pond was excavated, leading to a reasonable estimate of 320 interments within the small pond. All indications are that Windover residents, like other Floridians at this time, were egalitarian, exhibiting little social differentiation beyond the basics of age and sex (Hamlin 1998).

Sites of this antiquity are ephemeral; most terrestrial sites are limited to scattered lithics. Of the roughly 20,000 archaeological sites in Florida, only 250 are identified as Early Archaic (equivalent to Windover), while another 297 are identified as Middle Archaic (only slightly more recent than Windover). In a tabulation of 1,200 ^{14}C dates in Florida, only 7 sites have been directly dated to the interval between 6500 and 8500 BP, broadly bracketing the Windover site, which has been dated to circa 7400 BP. Regardless of which metric (however crude these may be) is applied, sites of this antiquity are rare. Within Florida, 5 sites (Windover, Republic Groves, Bay West, Little Salt Spring, and Warm Mineral Springs; Doran 2002b: 34) contain a disproportionate quantity of North American skeletal material prior to 6000 BP—comprising about 20 percent of all materials prior to 5000 BP (Doran 2002a, 2000b, 2000c). Taken in context, the large number of burials suggests that some central Florida groups were effectively identifying reliable and abundant resources, thus allowing a reduction in mobility coupled with a likely increase in sedentism, which in turn facilitated repetitive returns to the same ponds for funeral activities.

Windover is a pond with about two meters of standing water and a five-meter peat deposit forming the pond bottom. The approximate middle of these peat strata is where all burials were found. Seasonal fluctuations in rainfall influence pond depth, but palynological, petrographic, and macrobotanical analysis all indicate that it has been a persistent pond at least since the close of the Pleistocene, well prior to any evidence of human presence in the pond (10,750 BP [uncorrected years BP]; Doran, 2002a). In the first excavation season, a section of the pond was surrounded by an artificial sand dike, and well points were installed through this dike. This allowed excavation but required more maintenance and provided less water control than was desired. In the 1985 and 1986 excavation seasons, the entire pond was encircled with longer well points (seven meters) placed roughly every two meters around the pond perimeter. This proved far more effective.

Many burials were disarticulated, possibly from natural movement toward the deeper center of the pond (though clearly some disturbance resulted from

initial backhoe work, which accidentally revealed the site). Along the northern margin of the pond, more burials were intact; roughly seventy-five individuals of all ages and both sexes were relatively complete, and many burials included artifacts and handwoven fabrics. The burials were intentionally placed in the pond, in some cases being held in place by burial stakes, which occasionally pierced the handwoven fabric containers that enwrapped some of the bodies. The best interpretation is that at the time of deposition, the water was probably no more than mid-calf deep, and relatively shallow depressions were dug into the peat strata into which the bodies were placed (and at least in some cases physically pinned down). With continuous saturation and peat deposition, the bodies were in a near-optimum preservation context. The remarkably well preserved bones included ninety-one crania with preserved (saponified) brain masses retaining macroscopic, microscopic, and varying biomolecular details (Doran et al. 1986). From the outset, one of the most important research opportunities presented by Windover was the study of a large representative cross-section from a very early New World time interval that is bioarchaeologically poorly known. Windover is, from what we can tell, the largest of the pre-7000 BP skeletal samples in North America and possibly the New World.

Radiocarbon dates on human bone, peat, and artifacts directly associated with the intentional burials firmly place the site and the MNI of 168 individuals in the Florida Early Archaic, with a mean date of 7410 BP (uncorrected) (Doran 2002b). These radiocarbon-dated materials include one of the oldest directly dated bottle gourds (*Lagenaria siceraria*) north of Mexico (Doran et al. 1990). Other older skeletal collections exist but provide far smaller samples. A pH-neutral peat matrix, an anaerobic environment, and continual saturation provided near-optimal organic preservation with nearly equal numbers of males and females, adults and subadults (Doran 2002b).

A burial tradition involving aquatic burial or burial within peat bogs is known only in southern Florida; Windover (near modern Titusville, Florida) is the northernmost representative of the tradition. Bay West, Republic Groves (Doran 2002a), and Ryder Pond (Dickel, pers. comm.) exhibit almost identical burial strategies and are only slightly more recent (Middle Archaic, with the first two dated respectively at 6630 BP and 6133 BP; Ryder Pond is undated but appears to be of equivalent antiquity). Little Salt and Warm Mineral Springs also provide well-preserved aquatic burials, dating variously to between 6100 and 10,000 BP.

Florida contains the full spectrum of prehistoric traditions, from Paleoindian to contact and early mission period sites (Milanich, 1994). The Paleoindian presence is clear, and a number of sites have produced small amounts of human skeletal material; however, as is typical of Paleoindian sites, these sites

are much more likely to be represented by lithic remains. Some sites attest to megafauna exploitation, but the biomass of deer and smaller vertebrates was undoubtedly more consistently important to these early inhabitants. No Paleoindian site and no sites dating to the opening periods of the Archaic support anything but a terrestrial subsistence orientation. There is little question that some terrestrial sites in the coastal margin have been inundated by the rising sea levels, but so far the evidence indicates that the earliest subsistence orientations were almost exclusively terrestrial or focused on interior freshwater resources until the Middle Archaic, around 6000 BP (uncorrected; Milanich 1994). The stable isotope analysis of multiple Windover individuals supports this proposition (Tuross et al. 1994). More recent unpublished assays (Tuross, pers. comm.) indicate that the Windover people's diet did not come from the Atlantic Coastal Ridge, where the site is located. The isotopic signatures are a better match to those expected from the western sides of the St. Johns upland west of Windover. This and other archaeological reconstructions support a focus on terrestrial vertebrates and freshwater resources, excluding shellfish. After 6000 BP, shell fishing and an aquatic/riverine orientation on interior waterways and along the Gulf and Atlantic coasts expanded. Virtually all populations with access to such resources show this subsistence shift, and shellfish become both important and visible subsistence items in the archaeological contexts.

From roughly Gainesville south, this Archaic subsistence orientation would continue to postcontact times. There is no significant evidence of agriculture in this southern region, though many of these groups exhibit hallmarks of chiefdom-level societies approaching the complexity of groups that made the transition to agriculture. Such complexity in hunters-gatherers-fishers presents an interesting alternative to the widespread agricultural trajectory.

A Comparative Strategy

I have had a long-standing interest in accumulating data sets spanning time and space (Doran 1975, 1980). One such database is an inventory of North American (United States and Canada) skeletal samples (the NORTH database). The details of most of the sites in the data set are provided in Doran 2002b, though some new sites have been added since publication of this work. Initially begun as an inventory of pre-5,000-year-old skeletal samples, the scope expanded to include as many samples as possible that had sample sizes approaching 50 individuals, regardless of chronological placement. A second database used here includes postcranial measures (dominated by maximum long bone length, hence referred to as the LB data set). Recently the postcranial metrics from the Western Hemisphere database (WHDB; Steckel and Rose 2002a) were

incorporated into the LB data set. The LB/femur series contains information on 1,072 individuals from eighty-three North American sites. These and other databases that we are compiling (dental [metric and nonmetric], craniometric, and paleodemographic) continue to grow and are an attempt to create a robust inventory providing a number of interesting observations about long-term population trends.

The North American Skeletal Inventory

The skeletal inventory (NORTH database) includes information on 417 sites and 49,138 individuals. Most of the sites and samples come from Texas (5,330 individuals from 53 sites), New Mexico (5,243/21), Illinois (4,440/35), Tennessee (3,929/21), Florida (3,572/40), California (3,009/41), and Canada (5,572/32); collectively, these comprise about 63 percent of all individuals and 58 percent of all sites. Other states contribute fewer sites and individuals to the inventory. About two-thirds (67 percent, n=280) of the sites come from the past 2,500 years and contribute 43,352 individuals (88 percent of all individuals). Additional details on this inventory are presented in the Windover volume (Doran 2002b, 2002c). Minimally, this series includes the majority of both the oldest samples in North America and the majority of the large samples discussed in major journals. It thus forms the core of our understanding of North American bioarchaeology.

To facilitate an examination of this data set, it is partitioned into 2,500-year intervals (Table 3.1). The earliest (and clearly Paleoindian) interval, dating to before 10,000 BP, includes only fifteen sites (64 individuals), generally represented by one or two individuals, the skeletons of which are often very fragmentary. The sites are scattered across the continent. Three sites are from California and produced only 3 individuals. Four of these earliest sites are from Texas and produced 5 individuals. The only states producing more than three individuals are Washington, with 28 individuals, and Florida, with two sites, one of which (Warm Mineral Springs) produced 21 individuals (although possibly not all dating to this earliest interval). Other states with single individuals come from the continent's western interior—Kansas, Idaho, Montana, Nevada, and New Mexico. This distribution is basically a coast-to-coast, north-to-south thin distribution of sites. There is little evidence of clustering or concentrations of samples within any region. Clearly, the distribution of Paleoindian sites in general—basically based on diagnostic lithics (Anderson and Faught 2000) and sites producing skeletal samples—suggests a widespread low-density human presence across the continent. It could be argued that the fluted-point distribution shows some higher-density concentrations, more frequently observed in the eastern United States, though issues have been raised concerning

Table 3.1. NORTH Sample Distribution by Chronological Intervals

		Interval Composition (years BP)					
	Total	< 500	500–2499	2500–4999	5000–7499	7500–9999	> 9999
Sites	417	79	201	35	52	35	15
Minimum	1	32	23	1	1	1	1
Maximum	1,327	681	1,327	1,234	175	5	28
Median	69	109	90	71	5	1	1
Mean	116.7	171.2	148.4	128.2	22.9	1.3	4.3
SD	160.1	152.0	168.6	220.0	41.1	0.7	8.3
Total	49,138	13,525	29,827	4,487	1,191	44	64

Note: The NORTH sample is the inventory of sites and skeletal samples from North America, north of the Rio Grande. Date ranges are in uncorrected years BP. "Sites" refers to the number of sites or components within each interval. "Total" refers to the sum of individuals for all sites/components combined. All other categories refer to the number of individuals per site or component.

recovery and identification differences in the eastern United States (Anderson and Faught 2000), and this apparent geographical disparity of concentrations may be influenced by site visibility and modern population densities. It is simplest to think of this earliest interval (ignoring the possibility of a pre-Clovis presence because there are no potentially pre-Clovis skeletal samples) as representative of small, highly mobile groups seldom either staying in or returning to any location frequently enough to create sites with large numbers of burials. The majority of Paleoindian sites with skeletal material contain isolated burials and are typically not associated with significant accumulations of habitation debris.

In the next time interval, 10,000–7500 BP, an Early-to-Mid-Holocene interval, the number of sites more than doubles, to thirty-five sites. Of particular interest are the observations that the number of individuals recovered is smaller than that of the preceding interval (n=44), and that no single site contains more than five individuals, while only six of the sites contain multiple individuals (generally two, with the exception of the single site with five individuals). Most sites (n=22) from this interval cluster between 9000 and 9999 BP. The distribution, like that of the preceding interval, spans the continent. If there is any (even subtle) geographic change, it may be the appearance of sites in the northern reaches of the continent (Pennsylvania, Wisconsin, Minnesota, Alaska, British Columbia, and Ontario). Presumably, in the pre–10,000 BP interval, northern occupations were more restricted because of the cooler climate of the late Pleistocene. The general impression in this time interval is the suggestion of a widespread, thin but persistent distribution across the entire continent. Samples in this inventory for the first time appear in a number of other states and provinces, including Arizona, Colorado, Kentucky, Minnesota, Nebraska, Ohio, Ontario, Pennsylvania, South Carolina, Tennessee,

and Utah. At most, this might be interpreted as a very modest infilling process, particularly in the Midwest and the central part of the continent. The absence of sites with large burial numbers still argues for small, highly mobile populations. Many of the interpretations of this interval suggest that these groups were largely following a lifestyle very similar to that of the earlier Paleoindian tradition; biologically the interval is distinct primarily in the disappearance of the megafauna. Some researchers argue that in this interval, some groups were developing a clearer sense of place within a region. Perhaps a reduction in mobility occurred, reflecting a slow downward oscillation into more restricted regions. Such patterns are less clear from the skeletal distribution alone, and we are still examining regional differences and site frequency information. Perhaps this interval is best thought of as basically a continuation of an effective hunting-gathering extractive strategy utilizing a wide range of resources from many environments, with little apparent concentration on any resource subset. The disappearance of megafauna may be more profoundly significant to the archaeological community than it was to the people who lived through it.

In the 7500–5000 BP interval (some regional variant of Early/Middle or perhaps barely Late Archaic), the number of sites again almost doubles, to fifty-two sites. While the doubling in site counts is remarkable, what is even more dramatic is the change in the number of individuals, which increases about twenty-seven-fold, to 1,191. Clearly, these changes reflect significant departures from the apparent stability and continuity of the earlier intervals. Nearly 50 percent of the sites contain between 10 and 60 individuals, but only six of the sites contain more than 46 individuals. Seven of the sites contain 782 individuals (66 percent of the total interval inventory). This is the first interval to show a significant departure from the model of small, dispersed populations gradually infilling areas. From a geographic perspective, relatively little territory is added; new states entering the inventory are limited to Illinois, Indiana, Louisiana, Mississippi, Missouri, and Oregon. There is no clear and obvious chronological trend, and the larger samples are distributed over the entire 2,500-year interval. Many of the states, and by extension much of the geographic region, are still dominated by small samples of fewer than 10 individuals. There is also a trend toward increasing numbers of sites within individual states, which also translates into increasing numbers of skeletal samples within each state. The areas exhibiting the most striking increases are Florida (where the preservation in aquatic contexts contributes to a better inventory), California, and Illinois. The twenty-eight sites in these three states provide 74 percent (n=877) of the total inventory from this time interval.

It is easy to argue that gradual infilling was replaced by more substantial in-place increases during this interval. If the numeric increases were largely a reflection of improved preservation conditions (that is, more skeletal ma-

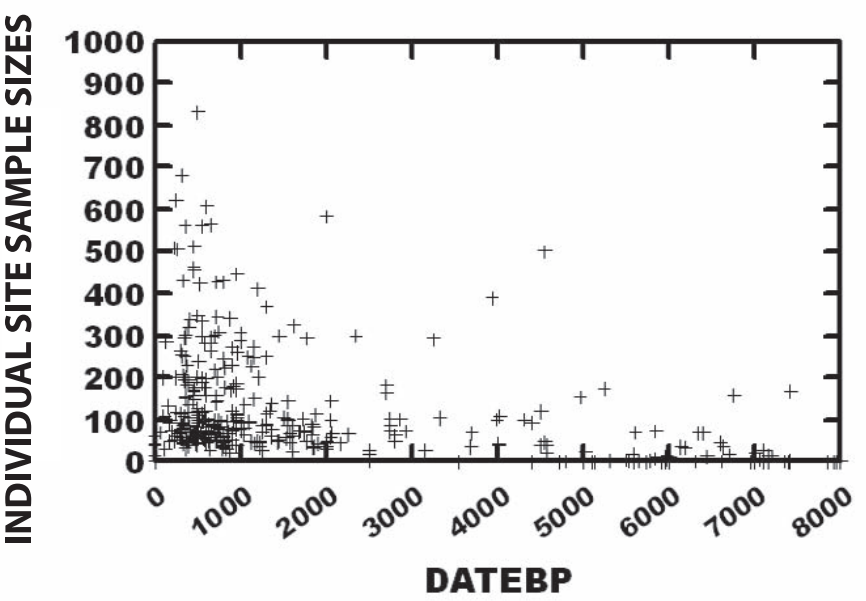

Figure 3.1. Chronological distribution of sample sizes in North America.

terial surviving), one would expect to see chronological skewing toward the interval's end (5000 BP), but this is not the case. There are, in fact, more individuals in the pre-6000 BP interval than in the post-6000 BP interval. The appearance of the Florida wet sites cannot account for the overall temporal distribution. Even excluding the Florida wet sites (Windover, Bay West, and Republic Groves), the sample from the pre-6250 BP interval totals 479 individuals, whereas there are only 269 individuals from the 6240–5000 BP interval. This strongly argues that it is not a preservation phenomenon but that these changes reflect in-place expansions and, for the first time, substantially larger local concentrations in some restricted geographic regions: in a sense, "hot spots" of population increase. There are, in all, fourteen sites with samples of greater than 20 individuals (Figure 3.1). From a broad perspective, it is in this interval that we see cultural traditions beginning to specialize or focus on resource subsets, with some perhaps shifting toward greater degrees of sedentism or at least some restriction in seasonal movements, reflecting the subsistence focus on the most reliable and productive resources within their territories.

The interval from 5000 BP to about 2500 BP (roughly some variant of Late Archaic/Woodland traditions) shows a number of interesting features, some of which reflect sample inclusion differences and others probably reflecting "real" differences. In this interval, the primary inclusion criterion was a sample

size of roughly 50 individuals at a given site—in the previous intervals, there was no sample size limitation, because we were trying to obtain as complete an inventory of the oldest samples in North America as possible. In reality, a number of sites in this interval fall below the normal inclusion level. In some cases, they may have had an early date placing them beyond the 5000-year window, or they are more recent components from sites with pre–5000 BP dates and were included to ensure that the inventory is as complete as possible. Even ignoring these slight shifts in the inclusion criterion, the number of sites with more than 50 individuals dramatically increases (though the number of sites actually decreases, to thirty-five, from the previous interval's higher count of fifty-two. However, there is no diminution in the total number of individuals represented. Though the number of sites is smaller, the total inventory nearly quadruples (n=4,487), with an average of 128 individuals per site. This is somewhat inflated by the presence of Indian Knoll (n=1,234) but reflects—and Indian Knoll is the exemplar of this pattern—the dramatic increase in sample sizes at individual sites. Even excluding Indian Knoll, the average sample size in this interval is 93. Again, there is no clear increase in sample sizes from the oldest to most recent periods, indicating that this is more than a simple preservation phenomenon.

Geographically, there is some adjustment but it is hard to interpret. Some states that had produced samples in the earlier intervals (Alabama, Mississippi, New Mexico, Nevada, Oregon, South Carolina, and Utah) drop out of this time interval, and only a few states (Missouri, Nebraska, and South Dakota) appear for the first time in this interval. These differences probably reflect sample coverage more than a real difference in population changes. However, the concentration of sites and the increase in sample sizes at individual sites may reflect geographic population/demographic changes building on those of the preceding interval. Florida, Illinois, Texas, and California continue to provide disproportionate numbers to the inventory and collectively contribute 27 percent (n=1,240) of all individuals in this interval. Even including the Indian Knoll outlier, the trend is the same; there are some areas that show significant localized population increases. Bioculturally, it could be argued that, at least in some areas, populations were increasing substantially at individual sites and within regions within states. Again these are logically the kinds of phenomena that would be driven by real changes in demographic experience and adaptive success often but not always associated with some experimentation with semidomesticated species. These changes most simplistically would thus reflect even greater in situ sedentism.

From 2500 to 500 BP (roughly pre-Mississippian to contact, with a slight reduction in the time interval to exclude postcontact burials), sample morphology changes even more. This is the interval in which agriculture, if it de-

veloped in a region, became the dominant subsistence strategy and changes in population size and density are most dramatic. The increase in total sample size is clear with respect to the total number of individuals (n=29,827) and the number of sites (n=201), a five-fold and a six-fold increase, respectively. The average sample size jumps to 148. A dramatic increase is evident in some geographic areas, particularly in some areas of the Southwest and Southeast. This is particularly noticeable in New Mexico, which shows an inventory of 34 sites contributing 3,837 individuals (an average of 113 individuals per site). Texas, where some groups shifted toward agriculture, shows similar increases, with 28 sites producing 3,530 individuals (averaging 126 individuals per site). Illinois and Florida produced 23 and 20 sites, respectively, contributing 3,739 and 1,746 individuals (with site averages of 195 and 163 individuals). Virtually all states in this interval for which we have information on more than one or two sites typically exceed 100 individuals per site. All these features indicate that this interval, even though simplistically constructed for these analytical purposes, exhibits dramatic population changes. This is certainly consistent with general cultural and subsistence reconstructions positing significant increases in site counts, population density, and population size in the past 2,000 years.

The last interval, the comparatively brief postcontact period (<500 BP), contains 13,525 individuals, with a mean sample size of 171 individuals, from 79 sites. The reduced number of years included in the interval logically results in a reduction in the number of sites and consequently overall sample size; however, at least hypothetically, this should not affect the calculation of average sample size. This is the interval in which contact impacted native populations through disease and conflict, an impact reflected in the reduction in mean numbers of individuals per site. In this interval, the states with the larger inventories—California, Texas, Florida, New Mexico, and Tennessee, all of which had dramatic increases in the previous time interval (mean sample size of 187, 126, 163, 113, and 273, respectively)—show a substantial reduction in mean sample size (47, 107, 94, 108, and 147). This, the most recent interval, should, if preservation were the driving force behind these patterns, show improved preservation, but in fact this is not the case. Regardless of these caveats and issues of sampling, the consistent regional decline (where we have a reasonable number of samples) is consistent with what would be expected with an increase in mortality rates and a reduction in fertility rates, coupled with a population decline, as a consequence of contact.

Femur Dimensions as an Indicator of Population Conditions

As part of the Florida State University's comparative effort, we are tabulating an inventory of postcranial dimensions. The data set contains information on 1,072 prehistoric individuals from North America (predominantly the United States) that have a maximum femur dimension (abbreviated as FEMU; Figure 3.2). Gender attribution is uncertain in many individuals, but the sample includes 435 males and 417 females (the male mean length is 448 millimeters; female, 415 millimeters). Approximately 700 of these individuals come from the Western Hemisphere database (WHDB; Steckel and Rose 2002a). The unsexed sample has both a mean and a median of 433 millimeters. This analysis will focus on femur length in a gender-free analysis, but obviously, mean and median values can be heavily influenced by the proportion of males and females.

The argument could be, and has been, made that maximum femur length can be used as an indicator of health (Steckel et al. 2002). Arguably, this is most appropriate when population continuity and origins are similar. The presumption is that differences in femur length (or stature, most frequently calculated on femur length) is heavily influenced by diet and health. Perturbations

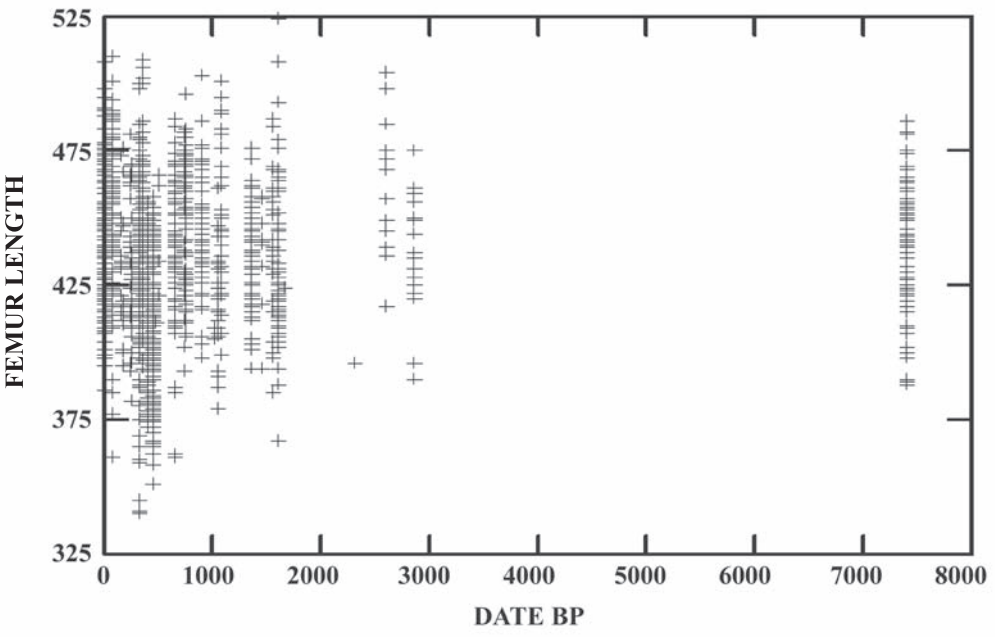

Figure 3.2. Maximum femur length (in millimeters) in North American samples.

in growth trajectories of a sufficient magnitude and duration result in length reductions. Fewer perturbations and nearer-optimal health conditions result in femur length and stature more closely approximating the maximum genetic potential.

Femur length shows several trends over time (Figure 3.2). Windover is the earliest sample in the data set, and the Windover series appears to be shifted toward larger values (all values are given in millimeters). This is noted in mean and median values (Windover male mean is 454, median is 455; Windover female mean is 419, median is 425; male combined with female mean is 439, median is 442). (By contrast, the post-Windover unsexed sample has a smaller mean/median value of 433 millimeters.) Several features are interesting even from this simplistic perspective. First the variability, here visibly illustrated by the plotted range (Figure 3.2), increases through time, with the more recent samples (particularly those postdating 1000 BP) showing very wide ranges with elevated maximum dimensions and smaller minimum dimensions. This is even more strikingly obvious in the samples that postdate 500 BP—essentially those occurring after contact. Greater fluctuations in metabolic, nutritional, and/or health stress in the contact period may explain this phenomenon. Fluctuations could be of a seasonal nature or on a longer cycle, so that in some years nearer-optimal growth conditions were attained, while at other times conditions were much worse and individuals were more heavily impacted. This is what would be expected in some marginal agricultural groups and in groups having difficulty in mediating the impacts of Western contact. It is worth noting that some of the smallest femur dimensions and lowest mean/median values are found in late agricultural sites in New Mexico: Hawaiku and San Cristobal, to be specific. These two sites also have very low health indices (Steckel et al. 2002; see Table 3.4). This is consistent with the position that overall metabolic/health stress is an important feature influencing metric features. Windover, by contrast, appears to have experienced less fluctuation in stress, with a population that may even have been relatively well nourished compared to those of later samples.

Other Population Comparisons

An analysis of Windover fracture patterns reveals several interesting phenomena (Smith 2003). Of the more than 8,700 elements more than 50 percent complete that were examined for this study, only 90 exhibited fractures (Table 3.2). Side differences in fracture prevalence were generally not significant. Of the 90 fractures, only 6 showed misalignments. Fracture prevalence in females (n=16) is only slightly higher than in males (n=13). No significant differences with respect to factors such as gender, age (Table 3.3), location, degree of heal-

Table 3.2. Windover Fracture Incidence by Element

Element	Number of Fractures Observed	Number of Elements Observed	Element Fracture Percentage
Cranium	5	102	4.9
Vertebrae	18	1,536	1.17
Clavicle	2	217	0.92
Scapula	1	73	4.1
Humerus	1	226	0.44
Radius	3	207	1.44
Ulna	15	227	6.6
Metacarpals	3	632	0.47
Phalanges	6	1,824	0.32
Ribs	29	612	4.73
Os coxae	1	142	0.7
Femur	2	238	0.84
Tibia	1	222	0.45
Fibula	2	209	0.95
Foot phalanges	1	1,156	0.08
Total	90	7,623	1.18

Source: After Smith 2003.

Table 3.3. Windover Fracture Incidence by Age Group

Age Group	Number of Individuals	Number with Fractures	Percentage of Total Fractures	Percentage of Age Group with Fractures
0–10	50	4	11.4	8.0
11–20	24	1	2.9	4.2
21–30	19	4	11.4	21.0
31–40	15	5	14.3	33.3
41–50	25	11	31.4	44.4
51–60	10	4	11.4	40.0
61+	13	6	17.1	46.2
Total	156[a]	35	99.9[b]	22.4

Source: After Smith 2003.

[a] Total number of individuals was 168, including 12 very fragmented/incomplete adults of indeterminate age.

[b] Total does not include individuals of indeterminate age.

ing, or severity were observed. Subadult fractures (0.05 percent) were rare even though subadults made up roughly half of the total sample.

The percentage of cranial fractures (4.9 percent) at Windover is slightly higher than any other element category, but most were not severe and all were well healed. Ribs are the next most commonly fractured element, with the right side having been more commonly fractured (n=15) than the left (n=8), though 6 rib fractures were unsided. Upper long bone elements (19 of 660) were more frequently fractured (2.9 percent) than lower long bone elements

(5/669; 0.1 percent). Of the long bones, the ulna (6.6 percent) and radius (1.4 percent) were the most frequently fractured elements. If fractured, vertebrae usually exhibited compression fractures, frequently associated with the decreased bone density concomitant with aging. Of the 168 individuals, 43 (22 percent) exhibited fractures. Some of these fractures, particularly those of the arms and ribs, may be related to subsistence strategies involving dugout canoes, in which falls against the gunwale during the loading and unloading of aquatic resources seems a likely high-risk activity.

In comparisons by Smith (2003) and Frantz (1989), fracture frequency is higher in later comparative Woodland samples, though Windover has slightly higher fracture prevalences than has been observed in a number of eastern U.S. Mississippian populations. The number of other Archaic data sets is small, but Windover has a slightly higher prevalence of fractures than comparative (and later) Archaic samples. Only a small number of these fractures seemed to be readily attributable to interpersonal violence; most appeared to have been related to accidental injuries (such as falls) and were generally well healed.

There is no difference in the mean age of males and females exhibiting fractures. Fracture prevalence peaks in the 40–50-year-old age category with respect to both the distribution of fractures and the percentage of individuals exhibiting fractures. This pattern no doubt reflects both the accumulative process of aging and a decrease in bone density with age.

Steckel and Rose (2002a, 2002b) have presented comparative data for a large (n=12,513) series of individuals from the New World. In the North American subset, there were 4,966 arm fractures, 5,547 leg fractures, and 5,165 cranial fractures. Compared to this continental-level pattern, Windover shows a much lower incidence of overall fractures, lower percentages of individuals with fractures, and a lower incidence of individuals with multiple fractures. Additionally, the ratio of upper-limb to lower-limb fractures at Windover is in direct opposition to what was observed in the Western Hemisphere database, in which lower-limb fractures were more numerous than upper-limb fractures. One interpretation noted earlier is that the Windover pattern may reflect injuries involving dugout canoes, which almost certainly were ubiquitous in Florida even at this early interval (Wheeler et al. 2003).

Porotic Hyperostosis and Cribra Orbitalia

Porotic hyperostosis (PO) and cribra orbitalia (CO), standard measures of nonspecific metabolic stress, have been tabulated in a variety of methods and manners for many sites. As part of her analysis of the Windover sample, Estes (1988) compared Windover prevalence rates to a small series of other samples primarily, but not exclusively, from the eastern United States. The Steckel and Rose Western Hemisphere database (WHDB; 2002a) contains information on

both these variables, which were scored either as absent or with the number (1–4) noted. Their database is a rich source of comparative possibilities. We tabulated the site-specific presence or absence rates, which could then be compared both to Estes' (1988) comparative series and to the Windover data. Table 3.4 illustrates this information for the North American Native Americans. Windover, as is typical, is the oldest series in the comparative group and

Table 3.4. Percentage of Porotic Hyperostosis and Cribra Orbitalia for North American Native Americans

Site/Sample	State/Region	Date BP	% PH	% CO	*N*	HI[a]	Reference
Windover	Fla.	7400	41.6	27.2	125	—	E 1988
Indian Knoll	Ky.	5300	8.2	2.6	24	—	E 1988
W38	Calif.	3834	0.0	0.0	47	79	S 2002
KIT	G.Lakes	2600	0.0	96.2	26	78	S 2002
DUF	Ohio	2500	95.7	95.7	70	72	S 2002
W43	Calif.	1359	0.0	0.0	201	80	S 2002
WO7	Calif.	1075	71.7	42.9	233	83	S 2002
Dol	Colo.	1050	58.1	69.8	43	60	S 2002
Libben	Ohio	1000	44.4	—	107	—	E 1988
Dickson Mound	Ill.	975	13.6	100.0	44	—	E 1988
Anasazi	N.Mex.	913	34.3	—	539	—	E 1988
PEA	G.Lakes	900	99.0	71.9	96	74	S 2002
Dickson Mound	Ill.	850	31.2	100.0	93	—	E 1988
SUN	G.Lakes	750	91.3	84.1	138	73	S 2002
Dickson Mound	Ill.	700	51.5	100.0	101	—	E 1988
Etowah	Ga.	700	7.1	—	299	—[b]	E 1988
MON	G.Lakes	650	98.4	82.0	122	73	S 2002
Averbuch	Tenn.	612	17.0	—	893	—	E 1988
Grasshopper	N.Mex.	612	3.8	14.0	390	—	E 1988
Channel Islands	Calif.	550	—	34.9	280	—	E 1988
Eiden	Ill.	460	51.7	100.0	31	—	E 1988
La8	N.Mex.	448	61.0	63.7	267	57	S 2002
Haw	N.Mex.	398	64.2	64.2	187	54	S 2002
BUF	G.Lakes	350	98.0	90.1	101	77	S 2002
303	S.C.	325	73.8	57.4	122	74	S 2002
301	S.C.	325	9.6	9.6	335	84	S 2002
WW7	Plains	240	55.7	56.4	149	74	S 2002
DW2	Plains	170	80.0	82.4	170	75	S 2002
DK2	Plains	155	59.0	61.5	39	82	S 2002
KX1	Plains	155	54.2	54.2	59	77	S 2002
N.W.	Coast	150	—	12.6	345	—	E 1988
BFT	Plains	75	86.6	86.6	67	82	S 2002
WLE	Calif.	75	78.9	85.6	90	73	S 2002
CRW	Plains	75	56.2	53.4	73	76	S 2002
CHY	Plains	71	88.1	90.5	42	73	S 2002

Source: Estes 1988 and Steckel et al. 2002.

Note: — = no data available.

[a] HI = Health Index, from Western Hemisphere database (S 2002: table 3.2, 73–74).

[b] Not included in the database and thus no health index is available.

has a relatively low prevalence of PO and CO, 41.6 percent and 27.2 percent respectively.

Of the thirty-five sites in this comparative group, only eleven sites have lower PO rates (it should be noted that three of these sites report 0 percent PO rates, which I must confess a certain skepticism about). Regardless of this issue, Windover was clearly experiencing less stress than most of the other sites in this series. In general, calculation of average PO rates by 500-year increments shows a persistent overall increase in PO rates by time, and most of the more recent sites show consistently higher PO rates.

The Windover cribra rate of 27.2 percent is the seventh lowest in the series (note that two sites report 0 percent rates—again a seemingly unusual phenomenon). Here again the prevalence of CO increases through time, and the more recent sites (particularly those less than 1,000 years old) generally show slightly higher CO rates. The combined percentage of PO and CO at Windover (69 percent) is the sixth lowest in the series, and again, this summed stress indicator points to an increase in metabolic stress through time in many populations.

These rates, and the chronological pattern, again support the proposition of changes in metabolic stress through time and generally indicate that the older North American populations—perhaps because of lower population densities, less crowding, smaller population size in general, and less competition—were experiencing less generic stress.

These features and other indicators of stress are used by Steckel and colleagues (2002) to calculate a general population score referred to as the Health Index (HI). We are in the process of calculating this for Windover, but the information in Table 3.4 suggests that the PO and CO rates, at least hypothetically, are more sensitive indicators of stress than is the HI, which does not show as consistent a chronological decline. The earliest samples for which it is calculated yield a relatively high value of 78 and averages about 73 for the more recent series.

An Overview and Plea

The examination of a variety of North American population data illustrates several issues. Chronological trends can be observed, and there is much to be said for a broader effort at developing integrated databases. Any one who has accumulated even small sets of data from multiple sites knows how time-consuming this process can be. In the best of all possible worlds, this integration should, in my opinion, be a more explicit disciplinary goal. We have been idiosyncratically pursuing our own narrow interests for too long. Steckel and Rose and their colleagues (2002a) are to be praised for their tabulation of a great

deal of information in a standardized format that has been made accessible to the widest possible audience (http://global.sbs.ohio-state.edu/western_hemisphere_module.htm). Others providing similar aggregations of data (Howells 1989; Jantz 1995 and various; Owsley and Jantz 1999; Gravlee et al. 2003) deserve our collective applause. As all osteologists are painfully aware, perfect sample comparability may be an elusive goal, but efforts at comparisons are also limited by the absence of collaboratively tabulated and centralized databases. Other disciplines have been more effective in addressing these issues, and such a broad integrative strategy is a valuable and realistic disciplinary goal that is long overdue.

A second obvious problem is the chronological unevenness of the existing sample series. In these comparative samples, the vast majority of individuals come from the past 2,000 years. Our understanding and appreciation of morphological and biocultural aspects of earlier populations are heavily influenced by this skewed distribution. Even so, sample sizes and sample density show subtle (as well as not so subtle) differences in distributions across the past 10,000 years. From what we can tell, the same phenomenon is repeated in South America. Substantial differences in geographic distribution suggest that "hot spots," or centers of more rapid growth, may have existed. Some local populations, in the case of California and Florida, were very early precursors for much later large population expansions that never shifted to agriculture. Other regions show even more dramatic changes that are coupled with agriculture. As other researchers have noted, many more-recent populations exhibit a variety of indicators suggesting fundamental changes in the prevalence and intensity of metabolic stress. Clearly, local/regional differences exist, and the identification and analysis of these patterns will provide a more detailed appreciation of biocultural adaptation. This approach will be greatly facilitated by large-scale databases.

4

Outer Coast Foragers and Inner Coast Farmers in Late Prehistoric North Carolina

DALE L. HUTCHINSON, LYNETTE NORR, AND MARK F. TEAFORD

In a previous reconstruction of populations inhabiting Georgia and Florida (Hutchinson et al. 1998, 2000), stable isotope analyses demonstrated that long-utilized dietary staples continued to be eaten alongside maize until European contact. Those foraged foods consisted of local marine resources for coastal populations and terrestrial resources for interior populations.

This chapter focuses on late prehistoric populations inhabiting the inner and outer coastal regions of North Carolina. We examine regional variation in the use of maize, and in the use of other subsistence resources, via skeletal and dental indicators traditionally used to examine the role of agricultural resources in stimulating changes in health status.

Materials and Methods

Thirteen populations (740 individuals) inhabiting the North Carolina inner and outer coast were used to reconstruct diet and to examine patterns of health and disease (Figure 4.1; Table 4.1). The populations can be divided into two broad ecological regions. The first region is the inner coast; it contains the terrestrial and interior freshwater river basins. In total, 183 individuals from Late Woodland and 10 individuals from Middle Woodland contexts were examined from the inner coast. Most of the Late Woodland individuals are from communal ossuaries (Hutchinson 2002). Table 4.1 presents the total number of individuals examined; however, not all individuals could contribute information for each category of skeletal lesion or modification discussed. Consequently, percentages presented in each separate lesion discussion frequently cannot be related to Table 4.1. A much more detailed discussion of the material presented in this chapter can be found in Hutchinson (2002).

The second region is the outer coast; it contains the coastal and estuary regions of the Pamlico and Albemarle sounds. The aquatic environment in these areas ranges from marine saltwater to brackish water zones. From this region, 532 individuals from Late Woodland contexts (1200–350 BP) and 15 individuals from Middle Woodland contexts (2300–1200 BP) were examined.

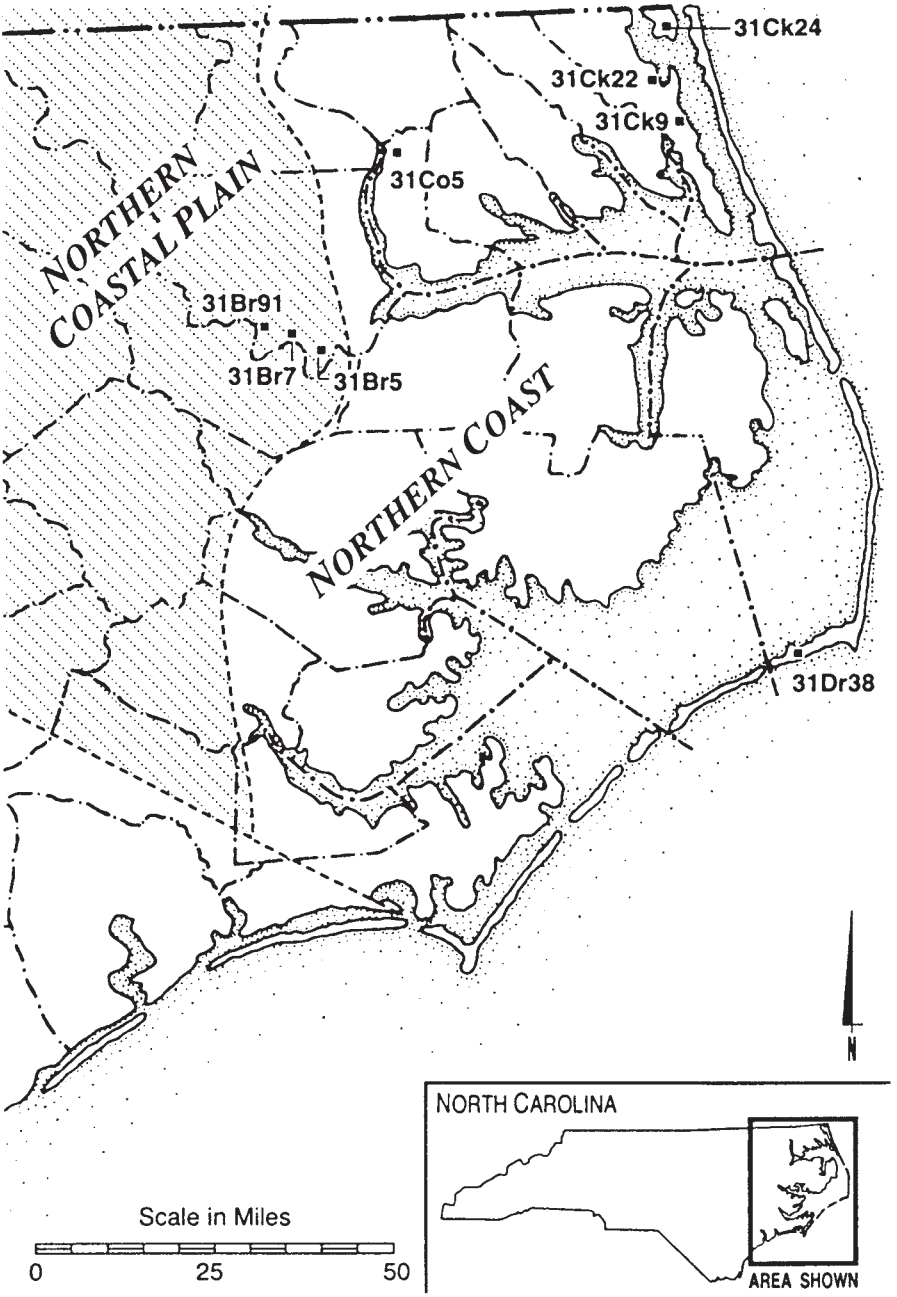

Figure 4.1. Map of study area with distribution of North Carolina populations.

Table 4.1. Number of Individuals Observed for Each Study Region

	Male	Female	Indet.	Subadult	Total
Inner Coast LW	19	30	62	72	183
Outer Coast LW	50	57	308	117	532
Inner Coast MW	3	4	2	1	10
Outer Coast MW	0	1	8	6	15
Total	72	92	380	196	740

Table 4.2. Number of Individuals Used for Stable Isotope Dietary Reconstruction

	Male	Female	Indet.	Subadult	Total
Inner Coast LW	5	7	14	11	37
Outer Coast LW	27	33	50	21	131
Inner Coast MW	0	0	3	2	5
Outer Coast MW	0	0	3	0	3
Total	32	40	70	34	176

Table 4.3. Stable Isotope Signatures by Locality and Chronology

	δ^{15}N[%]	δ^{13}Cco[%]	δ^{13}Cca[%]	Δ^{13}Cca-co
Inner Coast LW	14.0	-14.9	-8.1	6.8
Outer Coast LW	13.9	-11.8	-7.4	4.5
Inner Coast MW	10.9	-16.3	-9.7	6.7
Outer Coast MW	12.0	-15.7	-10.7	5.1

Table 4.4. Percentage of Teeth Affected by Carious Lesions by Age Category and Sex

	Male	Female	Indet.	Subadult	% Total Affected
Inner Coast LW	18	17	17	2	10
Outer Coast LW	20	24	17	2	14
Inner Coast MW	5	5	0	0	4
Outer Coast MW	0	0	17	0	11

We independently evaluated dietary content and the skeletal impacts of nutritional quality. Dietary reconstruction was performed by analyzing stable isotopes of carbon and nitrogen, as well as dental enamel microwear. Carbon was obtained from both collagen and mineral apatite to provide the best estimate of whole diet (Ambrose and Norr 1993) and was prepared by methods previously reported (Hutchinson 2002; Norr 2002). In total, 8 Middle Woodland and 168 Late Woodland individuals were used for stable isotope dietary reconstruction (Norr 2002; Table 4.2).

Molars from 27 outer coastal and 12 inner coastal Late Woodland individuals were used to assess dental microwear (Teaford 2002). They were cleaned,

and then impressions were made as described elsewhere (Teaford 2002). For each micrograph, five attributes were analyzed: average pit and scratch width (in micrometers), percentage of pits, number of microwear features, and homogeneity of scratch orientation (Teaford 2002).

Dental and skeletal pathological lesions were used to assess health and disease (Hutchinson 2002). All observations were made at the macroscopic level and were aided by a 10× magnification when further detail was needed. Presence and absence of lesions and behavioral alterations were recorded by individual whenever possible. We focus here on five pathological lesion types: caries, porotic hyperostosis, proliferative responses, enamel hypoplasias, and osteoarthritis.

Dental carious lesions were assessed in two separate counts: the number of carious teeth as compared to the total number of teeth (articulated or disarticulated), and the number of individuals with carious teeth (regardless of the number of carious teeth per individual). The two counts present very different kinds of data. The number of carious teeth accounts for disarticulated teeth that might not be counted if they could not be associated with a specific individual, while a single individual with bad dental health would likely have multiple carious teeth.

Inner Coast

The overall interpretation of the isotope signatures (Table 4.3) suggests that inner coastal populations had incorporated maize into their diets between the time period of the Middle Woodland populations and those of the Late Woodland period. However, evidence for variation in the diets between populations is present. Neither the isotope data nor the dental microwear data suggest homogeneity in the foods eaten or materials ingested, suggesting local variation in the subsistence regime.

In total, 162 Middle Woodland and 948 Late Woodland teeth were observed for carious lesions. No Middle Woodland subadults were affected by dental caries. Seven Middle Woodland adult teeth (4 percent) were affected by carious lesions (Table 4.4). Of teeth from Late Woodland individuals, 94 (10 percent) were affected. Late Woodland male (18 percent) and female (17 percent) teeth were affected equally.

When the percentage of individuals affected by carious lesions is considered, different patterns emerge (Table 4.5). Four Middle Woodland inner coastal individuals were affected by carious lesions (40 percent). Middle Woodland males exhibited extremely high percentages, with all individuals affected. Two Middle Woodland females (67 percent) exhibited carious lesions. Of Late

Table 4.5. Percentage of Individuals Affected by Carious Lesions by Age Category and Sex

	Male	Female	Indet.	Subadult	% Total Affected
Inner Coast LW	67	77	19	21	31
Outer Coast LW	84	77	53	11	50
Inner Coast MW	100	67	0	0	40
Outer Coast MW	0	0	0	0	0

Table 4.6. Percentage of Individuals Affected by Porotic Hyperostosis by Age Category and Sex

	Male	Female	Indet.	Subadult	Median
Inner Coast LW	42	32	11	20	26
Outer Coast LW	56	63	29	9	42.5
Inner Coast MW	0	0	0	0	0
Outer Coast MW	0	0	0	0	0

Table 4.7. Percentage of Individuals Affected by Enamel Hypoplasia by Age Category and Sex

	Male	Female	Indet.	Subadult	Median
Inner Coast LW	0	33	0	0	0[a]
Outer Coast LW	8	7	10	9	8.5
Inner Coast MW	22	8	8	18	13
Outer Coast MW	0	0	0	0	0
Age/Sex Median	15	8	9	14	

[a] Too few individuals for median to be calculated.

Table 4.8. Percentage of Individuals Affected by Proliferative Responses by Age Category and Sex

	Male	Female	Indet.	Subadult	% Total Affected
Inner Coast LW	0	10	6	1	6
Outer Coast LW	8	12	9	2	8
Inner Coast MW	0	40	0	0	20
Outer Coast MW	0	0	0	0	0

Woodland individuals, 31 percent were affected by carious lesions. Females (77 percent) were more often affected than males (67 percent). Subadult frequencies were quite high, with 21 percent of individuals affected by carious lesions.

The relationship between diet and iron-deficiency anemia has long been of interest to paleopathologists, and maize has often been implicated as a primary source of anemia in the Americas (Stuart-Macadam 1987b). Maize contains phytates that block the absorption of iron, and as a nonheme iron–containing food, it allows less iron to be absorbed. However, Layrisse and coworkers

(1968) have shown that absorption of nonheme iron from maize is increased substantially when maize is combined with fish.

Porotic hyperostosis is often interpreted to be a signature of iron-deficiency anemia, although there is much research to suggest that there are many other contributing factors. No Middle Woodland individuals were observed with porotic hyperostosis (Table 4.6). Late Woodland adults and subadults exhibited nearly identical prevalence (21 percent and 20 percent, respectively). Females (32 percent) were affected less frequently than males (42 percent).

Enamel hypoplasias were observed when the dentition was articulated and included at least one maxillary or mandibular anterior tooth, when teeth were not obscured by calculus and were not worn beyond half of the tooth crown. For the Middle Woodland, 1 adult female (out of 10 individuals examined) had enamel hypoplasias (10 percent of total adult population, 33 percent of females). For the Late Woodland, 104 individuals (70 adults) were examined (Table 4.7); 7 (10 percent of adults) displayed hypoplasia. Males (22 percent) were much more frequently affected than females (8 percent). Subadults had relatively high frequencies of enamel hypoplasia (18 percent).

A variety of stimuli (for example, trauma, infection, and injury) can cause inflammatory responses of the periosteum and endosteum (Walker et al. 1997). Thus, proliferative responses (periosteal reactions, osteomyelitis) are not strictly caused by infection, but their distribution by skeletal location, sex, and age can provide valuable clues to differential diagnosis of specific infectious diseases.

Two Middle Woodland females (40 percent of all MW females) exhibited proliferative responses (Table 4.8). Eight (6 percent) Late Woodland individuals were affected by proliferative responses. Three of those were females (10 percent); no identifiable males were affected. One subadult (1 percent) exhibited proliferative responses.

Systemic infections were identified using the criterion of either multiple elements affected with similar lesions in a single individual or distinctive lesions (for example, stellate scars). Two individuals (20 percent) from the Middle Woodland period were affected by systemic infections. In the Late Woodland, six individuals (3 percent; Table 4.9) were affected by systemic infections. More females (13 percent) were affected than males (0 percent).

No diagnostic criteria of treponemal infection were found in Middle Woodland populations. In the Late Woodland, cranial lesions indicating probable treponemal infection (healed stellate lesions) were observed for three females (14 percent of females).

No osteoarthritis was observed for Middle Woodland individuals (Table 4.10). Vertebrae were commonly affected by osteophytic spurs and Schmorl's nodes in Late Woodland populations of both regions. Of adult vertebrae (all

Table 4.9. Percentage of Individuals Affected by Systemic Infections by Age Category and Sex

	Male	Female	Indet.	Subadult	Median
Inner Coast LW	0	13	2	1	3
Outer Coast LW	16	12	1	0	3
Inner Coast MW	0	40	0	0	20
Outer Coast MW	0	0	0	0	0

Table 4.10. Percentage of Individuals Affected by Osteoarthritis by Age Category and Sex

	Male	Female	Adult	Subadult
Inner Coast LW	30	<1	48	0
Outer Coast LW	15	8	5	0
Inner Coast MW	0	0	0	0
Outer Coast MW	0	0	0	0

Note: Percentage calculated from minimum number of individuals (MNI).

types combined), 48 percent exhibited osteoarthritis. Most of these were male vertebrae (30 percent of total male vertebrae), while females exhibited very little osteoarthritis (less than 1 percent). Lumbar vertebrae were most commonly affected for males (80 percent), while only cervical vertebrae were most commonly affected in females (20 percent).

Outer Coast

On the outer coast, dietary signatures suggest that maize was absent from the diet during both the Middle and Late Woodland periods (Table 4.3). As was the case for the inner coast, there is substantial variation in the dietary signatures and dental enamel microwear between the populations, suggesting local variation in diet selection (Norr 2002; Teaford 2002).

Middle Woodland teeth (n=47) and Late Woodland teeth (n=3,268) were observed for carious lesions. No Middle Woodland subadults were affected by carious lesions (Table 4.4). Five Middle Woodland adult teeth (11 percent of total) were affected by carious lesions. Twenty-one Late Woodland subadult teeth (2 percent of total) and 461 adult teeth (14 percent of total) exhibited carious lesions.

No identifiable Middle Woodland individuals had carious lesions (Table 4.5). In contrast, Late Woodland individuals frequently suffered from carious lesions (n=98; 50 percent). Males suffered from carious lesions (84 percent) more frequently than did females (77 percent).

No Middle Woodland individuals were affected by porotic hyperostosis. Late Woodland adults (36 percent) were affected by porotic hyperostosis much more frequently than subadults were (9 percent; Table 4.6). Differences in porotic hyperostosis between males and females were also apparent in the Late Woodland; females (63 percent) were affected more than males (56 percent).

No Middle Woodland individuals exhibited enamel hypoplasias. Of 196 Late Woodland adults examined for enamel hypoplasia, 12 (9 percent of adults) displayed hypoplasia (Table 4.7). Male (n=3; 8 percent) and female (n=2; 7 percent) frequencies were nearly identical. Subadult frequencies were low (n=5; 9 percent).

No cases of proliferative responses were found for Middle Woodland individuals (Table 4.8). However, 8 percent of the Late Woodland individuals exhibited proliferative responses. Adults (10 percent) were more often affected than subadults (2 percent). Females (12 percent) were more often affected than males (8 percent).

Eighteen of the Late Woodland adults (4 percent) had systemic infections (Table 4.9). Males (n=8; 16 percent) were more often affected than females (n=6; 12 percent). Nineteen individuals had cranial stellate lesions indicating treponematosis. Males (n=9; 23 percent) were more frequently affected by stellate lesions than females (n=7; 17 percent). No subadults exhibited systemic infections.

As was true for the inner coast, no osteoarthritis was observed for Middle Woodland outer coastal individuals (Table 4.10). Five percent of adult vertebrae (all types combined) exhibited osteoarthritis (15 percent of male vertebrae, 8 percent of female vertebrae). Vertebral osteoarthritis for outer coastal males most commonly occurred on the lumbar vertebrae (77 percent). Females exhibited osteoarthritis only on the cervical vertebrae (3 percent).

Discussion

TEMPORAL TRENDS IN NORTH CAROLINA

Inner coastal populations experienced an increased prevalence of carious lesions from the Middle to Late Woodland periods, coincident with an increased dependence on a C_4 plant, most likely maize. The number of individuals with carious lesions appears to decrease from the Middle to Late Woodland, as does enamel hypoplasia, proliferative responses, and systemic infections. However, the small sample size (n=10) of the Middle Woodland sample warrants caution in making this interpretation, as a single positive case is inflated as a percentage.

Outer coastal frequencies of carious lesions for teeth and for individuals increase from the Middle to Late Woodland. There is virtually no evidence for any other pathological lesion type in the Middle Woodland period. Given the small Middle Woodland sample size (n=15), the absence of positive cases could be sample bias or could indicate real temporal trends in health and disease.

COMPARISON OF THE INNER AND OUTER COASTS

Stable isotope dietary reconstruction supports the hypothesis of separate dietary trends for the North Carolina inner and outer coasts. The inner coastal populations adopted maize agriculture after AD 1000, but outer coastal populations continued to rely primarily on oceanic and estuarine resources. In opposition to the expected patterns, the nonagricultural outer coastal populations are the ones that almost uniformly exhibit the higher frequencies of skeletal and dental pathology generally associated with increased reliance on maize.

For both the Middle and Late Woodland periods, carious lesion frequencies were higher for the teeth of outer coastal populations. Adult differences between the Late Woodland inner and outer coastal individuals affected by carious lesions are statistically significant ($p \leq .01$).

Outer coastal Late Woodland adults (36 percent) were affected by porotic hyperostosis much more frequently than those from the inner coastal region (21 percent; statistically significant, $p \leq .01$). Late Woodland inner coastal adults and subadults exhibited nearly identical prevalence (21 percent and 20 percent, respectively). For the outer coastal Late Woodland populations, however, adult frequencies (36 percent) were dramatically greater than those of subadults (9 percent).

For the Late Woodland, adult frequencies of enamel hypoplasia were slightly higher for outer coastal (10 percent) as compared to inner coastal (8 percent) individuals. Inner coastal subadults (18 percent) seemed to exhibit higher frequencies than outer coastal subadults (9 percent).

On the outer coast, more Late Woodland adults (10 percent) were affected by proliferative responses than on the inner coast (6 percent). Subadult prevalence for the inner coastal (1 percent) and outer coastal populations (2 percent) was low. Many of these proliferative responses can probably be attributed to treponemal infections; sixteen outer coastal and three inner coastal Late Woodland individuals had stellate lesions characteristic of treponemal infection.

In the Late Woodland, postcranial lesions including tibiae with anterior crest apposition suggesting treponemal infection were also common among

outer coastal populations. Saber tibiae, observed less frequently, were also present among outer coastal populations.

No osteoarthritis was observed for Middle Woodland individuals. With all vertebrae combined, inner coastal individuals were affected far more frequently than outer coastal individuals (statistically significant, $p \leq .01$). With regard to other postcranial elements, particularly the radius and patella, inner coastal Late Woodland individuals display a higher frequency of osteoarthritis than those of the outer coastal populations.

COMPARISONS BY SEX

In the Late Woodland groups, the frequency of teeth affected by caries is generally the same for males and females in the two regions. Outer coastal males (individuals) suffered more carious lesions (84 percent) than did outer coastal females (77 percent), but inner coastal females (77 percent) exhibited higher frequencies than were evident for inner coastal males (67 percent).

Differences in porotic hyperostosis between males and females are also apparent in the Late Woodland populations. Outer coastal females (63 percent) were affected more than males (56 percent), whereas inner coastal females (32 percent) were affected less than males (42 percent).

Outer coastal male (8 percent) and female (7 percent) frequencies of enamel hypoplasia are nearly identical, but inner coastal males (22 percent) have higher frequencies than females (8 percent) exhibit.

Females (12 percent, outer coast; 10 percent, inner coast) were more frequently affected than males (8 percent, outer coast; 0 percent, inner coast) by proliferative responses. However, outer coastal males exhibit higher frequencies of systemic infections and stellate lesions. The percentage of male vertebrae affected by osteoarthritis for the inner and outer coasts is very similar. Only cervical vertebrae were observed with DJD for females, with the inner coastal females exhibiting higher frequencies of affected vertebrae (20 percent) than those of outer coastal females (3 percent).

COMPARISONS WITH COASTAL GEORGIA AND NORTHERN FLORIDA

The skeletal and dental pathology data from coastal Georgia and northern Florida (Larsen et al., this volume) show several differences in the adaptive strategies and consequences employed there as compared to coastal North Carolina. Carious lesion frequencies (for teeth) from the Georgia coast and northern Florida indicate a clear trend toward increased caries frequencies after AD 1000. While an increase in carious lesion frequencies occurs on the

North Carolina coast, the distinct differences between subregions seen there do not occur in Georgia and Florida. Similarly, temporal increases for porotic hyperostosis and proliferative responses on the Georgia coast and in northern Florida also occur in North Carolina, but there are dramatic differences in lesion frequency between the inner and outer coasts of North Carolina.

Conclusions

The evidence from late prehistoric North Carolina indicates that the transition to agriculture (and its effects on coastal populations) was localized and variable. The dental microwear and stable isotope dietary reconstructions indicate considerable dietary variability, probably attributable to the exploitation of local ecosystems. Local resources appear to have exerted considerable influence on the timing and degree of domesticated plant adoption on the outer coastal populations at times when the populations of inland areas pursued full-fledged agriculture.

Late prehistoric North Carolina coastal populations, although they exploited local ecozones, also exhibit some similarities in diet associated with their exploitation of both saltwater and freshwater environments. There is no evidence for maize consumption during either period on the outer coast, where diets apparently focused on marine fish and marine invertebrates but lacked maize.

Middle Woodland inner coastal populations also display no evidence of maize in the diet, but Late Woodland inner coastal populations relied heavily on freshwater fish, with a ^{13}C-rich carbohydrate source that is undoubtedly maize.

Dental and skeletal pathological lesions were used to assess nutritional adequacy of the diet as well as other health consequences of dietary preferences. Although caries are usually attributed to a diet with an emphasis on cariogenic substrates, rates are actually higher for outer coastal populations than inner coastal populations in the Late Woodland, regardless of whether the frequencies are based on the number of teeth affected or the number of individuals affected. Moreover, Middle Woodland populations who were not maize horticulturalists exhibited the highest percentage of individuals affected by carious lesions.

No cases of porotic hyperostosis were observed for Middle Woodland individuals. In the Late Woodland, frequencies of porotic hyperostosis and proliferative responses are higher for Late Woodland adults on the outer coast than for those on the inner coast. Intestinal bleeding attributable to the ingestion of parasites with seafood may be the cause of the high frequencies of porotic hyperostosis in Late Woodland coastal North Carolina populations (Hutchin-

son 2002). Subadult frequencies for porotic hyperostosis, however, are higher for inner coastal populations. Subadults are often given a starchy cereal during weaning. The most likely cereal for the inner coastal populations would have been made of maize, thus contributing to high frequencies of porotic hyperostosis among this age group.

In the Middle Woodland period, proliferative responses were more common for inner coastal individuals, but that pattern was reversed during the Late Woodland, when outer coastal individuals were more commonly afflicted. In both periods, females were far more commonly affected than males. Many of the proliferative responses, especially for Late Woodland inner and outer coastal populations, were undoubtedly the result of treponemal infections. The presence of cranial stellate scars for three Late Woodland inner coastal and nineteen outer coastal individuals—as well as the often extreme periosteal and endosteal apposition, combined with lytic activity—makes this diagnosis fairly certain. Four outer coastal individuals (two males and two females) exhibited nasal remodeling similar to that seen in treponemal infections. Of the ten outer coastal and fifteen inner coastal Middle Woodland individuals observed, no stellate scars, nasal remodeling, or long-bone lesions suggestive of treponemal infection were observed.

No cases of osteoarthritis were observed for Middle Woodland individuals. In the Late Woodland, osteoarthritis of the vertebrae was higher for inner coastal individuals. This is an unexpected difference, given previous research showing generally lower rates of vertebral osteoarthritis for farmers as compared to foragers (Larsen 1997). We speculate that continued emphasis on foraging or frequent mechanical demands attributable to bending or carrying are responsible for the high rates of osteoarthritis.

Metabolic stress, as measured by enamel hypoplasias, appears to have been more common for inner coastal individuals during both the Middle Woodland and Late Woodland periods. Subadults were especially prone to enamel hypoplasias in the inner coastal region during the Late Woodland, after the incorporation of maize into the diet.

The frequency of carious lesions, porotic hyperostosis, and proliferative responses should be higher for the inner coastal populations consuming maize (as suggested in numerous other studies) than those from the outer coast, who were not consuming maize. They are, however, more frequently found in the outer coastal populations, suggesting that the association between increased pathology and agriculture is not simply a consequence of diet alone.

These important reversals in the trends expected for inner coastal agriculturalists and outer coastal foragers necessitate alternative explanations for the causes of those lesions. As an example, dental damage is a frequent condition in coastal populations (Hutchinson 2002, 2004), and we propose that it is a

precursor for subsequent infections of teeth and adjacent alveolar bone. The numerous grooves and fissures of the premolars and molars provide a locus for dental caries; dental chipping would provide further loci of the same type and also would expose the dentin to infection (Hutchinson 2002).

The different patterns exhibited between populations inhabiting the inner and outer coasts of North Carolina are not simply differences between small subregions, however. Outer and inner coastal males exhibit higher frequencies of dental chipping than females do, suggesting either dietary or masticatory differences between men and women. Stable isotope nitrogen and carbon signatures do not support different diets for males and females, as there are no significant differences. The differences in dental chipping but the similar isotope signatures suggest that there were important differences in either the consumption or the processing of food, such as the degree of grit remaining or the frequency with which shells were cracked using teeth. Men may have been consuming shellfish directly at the foraging site and women boiling or otherwise washing the shellfish before consumption afterwards.

We draw three main conclusions from our investigation. First, ecological diversity can play a critical role in the adoption of new domesticated resources and the maintenance of those long-present in the dietary repertoire. In coastal North Carolina, ecological distance is clearly more important than geographic distance.

Second, as paleopathologists, we need to be more conscious about incorporating alternative interpretations for disease etiology. Although in the past we lacked the technology to make determinations about the specific items included in the diet, the technology is now in place to assess diet separately from skeletal and dental lesions. That ability enables us to approach multiple explanations for pathological lesions.

Third, assessment of the impact of agriculture must incorporate male and female roles in the subsistence economy. Otherwise, important differences between either male and female subsistence roles or male and female consumption may be overlooked. In this study, the demonstration that consumption was not responsible for differences in dental chipping and carious lesions enables alternative behavioral explanations.

The study from North Carolina supports the view that there is no single agricultural transformation but instead many agricultural transformations with their own unique circumstances. Careful scrutiny of local ecology and behavior will yield better reconstructions of the process and history of incorporating domesticated plants into the diet.

5

Health and the Transition to Horticulture in the South-Central United States

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Given the system of chiefdoms that characterized nearly the entire southeastern United States just before European contact, this region offers an ideal setting in which to investigate the transition from a highly egalitarian to a ranked political system. The transition, however, took place in many ways and times in accordance with the variety of environments present. The consequent variation in settlement size, domesticated and wild resource utilization, and social differentiation in turn results in variation in biological response (Lambert 2000). Because most prehistoric populations resided in river valleys, these physiographic features will be used as a natural organizational scheme to investigate the health patterns associated with adoption of horticulture in the states of Tennessee, Mississippi, and Alabama (Figure 5.1).

The faunal and floral assemblages from archaeological sites in the Deep South evidence consistent change in subsistence patterns from the Archaic period (circa 7000–3500 BP) through the Woodland Period (3500–1000 BP) to the Mississippian period (circa 1000–500 BP). In general, Middle and Late Archaic populations appear to have relied heavily on nuts—including acorns, walnuts, and especially hickory nuts—as their main plant resources (Yarnell and Black 1985). Evidence for faunal resources is more problematic, though it generally points to the importance of mussels and deer (Boyd and Boyd 1989). The earliest evidence of semidomesticated seed use has been identified at some sites in Tennessee during the Late and Terminal Archaic periods (Chapman and Shea 1981; Boyd and Boyd 1989), but populations in Alabama and Mississippi began to utilize seeds only in the Early Woodland (Fritz and Kidder 1993). The cultigens involved were generally quite similar, however, comprising starchy weeds such as sumpweed and goosefoot. Dependence on these products increased steadily throughout the Woodland period, especially as the inhabitants of the region became increasingly sedentary. By the Late Mississippian period, reliance on wild food resources declined significantly in favor of agricultural foodstuffs (Chapman and Shea 1981). Faunal remains point to continuing use of deer, squirrels, and rabbits (Smith 1975).

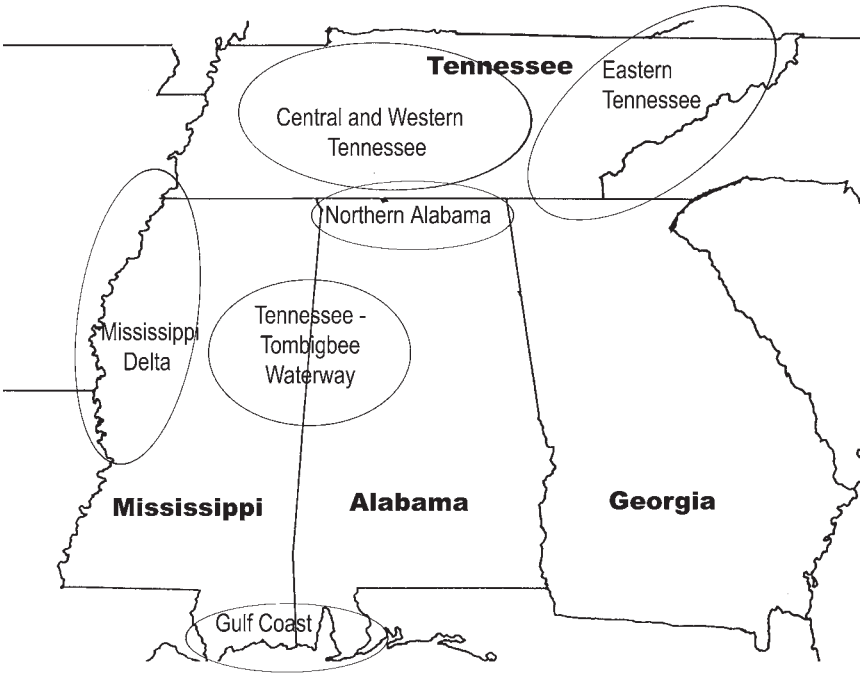

Figure 5.1. Map of study area in the south-central United States.

In addition to environmental variation, health patterns of the Mississippian period reflect biases related to sociopolitical organization inherent in the samples. Many studies of Late Mississippian sites have shown differences in access to resources among status groups (Van Derwarker 1999), which in turn may have had biological consequences. Unfortunately, there has been an overrepresentation of elites within populations, possibly because of the tendency for archaeologists to focus on assessing larger mound structures rather than analyzing the health status of the whole population (Hatch and Willey 1974; Hatch et al. 1983; Eisenberg 1991; Betsinger 2002). In recent years, this has been rectified somewhat, as more and more of the skeletal series analyzed come from small hamlets. Their inhabitants would be expected to have enjoyed greater access to wild resources to supplement their diets compared to their counterparts in larger communities. Furthermore, they would also be expected to have enjoyed healthier lives, since transmission of infectious disease should have been more difficult in these settings of lower population density. Such differences must be kept in mind in interpreting results.

Eastern Tennessee

The eastern Tennessee sites are primarily located around the fertile lands surrounding the eastern portion of the Tennessee River and its many tributaries. The Archaic/Late Woodland populations here include Eva (Lewis and Kneberg 1961), Hiwassee Island (Lewis and Kneberg 1979), Cherry, and Ledbetter, whereas the Mississippian period groups are Hiwassee Island (Lewis and Kneberg 1979), Citico, Ledford Island, Mouse Creek (Berryman 1980), Rymer, Toqua (Parham 1982; Parham and Scott 1980), Tomotley (Scott and Parham 1978), Dallas (Hatch and Willey 1974; Berryman 1980; Hatch et al. 1983), and Plum Grove (Wilson 1984). Many of these archaeological sites are found in transition areas between environmental zones, which serve to increase subsistence opportunities.

The rise of agriculture in this region was characterized by a gradual increase in domesticated plants in the Late Woodland, followed by a rather sudden shift to a heavy reliance on agricultural foodstuffs early in the Mississippian period (Boyd and Boyd 1989). Researchers suggest an overexploitation of resources and increased competition among local populations. This competition arguably was the cause of intraregional conflicts, evidenced by trauma and mutilation found in skeletal remains beginning in the Archaic (Smith 1996) and continuing through the Mississippian period (Berryman 1981; Lahren and Berryman 1984; Smith 1996). Mass migrations of invaders replacing Archaic and Woodland peoples may also have taken place. Some evidence shows very rapid biocultural changes in the archaeological record (Lewis and Kneberg 1979). Furthermore, in craniometric analysis of seventeen Late Mississippian sites, Berryman (1980; compare Boyd 1986) found tentative support for a movement of middle Tennessee people into eastern Tennessee. The possibility of a lack of genetic continuity complicates interpretations of differences in biological characteristics, such as stature.

When health variables are considered (Table 5.1), prehistoric stature in eastern Tennessee appears to have remained stable or perhaps even increased over time (Hinton et al. 1980; Boyd and Boyd 1989). The most comprehensive study of height patterns in the area was conducted by Boyd and Boyd (1989), who found an increase in mean femur length for both males and females in an early sample composed of four Archaic sites compared with late samples from six Late Mississippian sites. However, the authors note that the average length by individual site in each time period varies considerably and that the increase overall was small (Boyd 1986; Boyd and Boyd 1989). Furthermore, differences in stature among groups are as likely to be the result of regional variation as of temporal variation. Table 5.1 includes all the reported mean stature estimates, based on mean femur lengths calculated using Trotter and Gleser's (1952, 1958) formulae for Mongoloid males and White females.

Table 5.1. Mean Stature Values and Proportion of Total Population Displaying Various Pathologies at Sites in Eastern Tennessee

Period		**Stature (cm)**		**Pathology**			
Site	(*N*)	Males (*N*)	Females (*N*)	Anemia (%)	Inf (%)[a]	LEH (%)	Caries/Ind.[b]
Archaic							
Eva		166.5 (24)	154.0 (21)				1.3[c]
Cherry		167.3 (10)	156.6 (10)				1.3[c]
Ledbetter		167.9 (12)	158.1 (5)				
Woodland							
Hiwassee Is.					.57		
Mississippian							
Hiwassee Is.					.71		
Citico				.29	.14	.52	
Ledford Island		168.0 (41)	154.9 (41)		.20		
Mouse Creek		168.7 (8)	156.0 (9)		.00		
Rymer		168.5 (21)	156.8 (15)		.25		
Toqua		167.8 (32)	156.6 (37)	.65	.44	.27	3.6
Tomotley		166.4 (7)	160.0 (11)	.21	.07	.30	
Dallas sites		168.4 (117)	157.9 (94)				
Plum Grove			154.4 (1)		.00	.56	

[a] Includes all forms of infection.

[b] Average number of caries occurring per scorable individual.

[c] Caries rate for Eva, Cherry, and Anderson combined.

Boyd and Boyd (1989) also included midshaft robusticity measurements in their study in an effort to identify differences in mechanical loading attributable to different activities. They did not find significant changes in femoral robusticity, suggesting that biomechanical factors did not affect the changes in femoral length. Boyd and Boyd's (1989) investigation also found that sexual dimorphism in femur length and robusticity did not change over 7,500 years. Joerschke (1983), however, did report some evidence that Archaic females were much smaller than Late Mississippian females, without male stature changing appreciably over time.

Studies of other health indicators are less comprehensive. Few data concerning infection rates are available for eastern Tennessee. Lewis and Kneberg (1979) report that diseases such as periostitis were fairly prevalent at Hiwassee Island in the Late Mississippian Dallas skeletons, although they were almost absent among earlier Woodland burials. Frequencies of arthritis studies of Archaic sites also vary. A study of a small sample of skeletons (*N*=23) from the Pisgah component (Late Mississippian) at the Plum Grove site showed that all mature adults had some amount of osteoarthritis (Blakely and Beck 1984). An analysis of Toqua by Parham and Scott (1980) found that rates of porotic hyperostosis varied between age groups and possibly between status groups, with high-status groups (buried in mounds) having slightly less porotic hy-

perostosis than low-status groups. Rates at Toqua were also less than those at Dixon, perhaps as a result of better access to game.

Evaluations of dental pathologies are more numerous, and rates between earlier and later groups in the same area generally exhibit an increase over time. Smith's (1983) analysis of the Late Mississippian population at Toqua showed that the frequencies of dental caries and antemortem tooth loss are dramatically higher than in Archaic groups in the same area. Among the Archaic individuals, dental caries occur almost exclusively in the cervical region. Lewis and Kneberg (1979) note that low attrition is found in the Hiwassee Island population, despite heavy reliance on freshwater clams. Mississippian populations, which became increasingly dependent on maize agriculture, tend to display even higher rates of dental pathologies (Wright et al. 1973; Boyd et al. 1983; Blakely and Beck 1984). Odontometric data show a drastic reduction in the size of molars beginning after the Woodland, suggesting a new set of selective forces associated with a changing diet (Hinton et al. 1980, Smith et al. 1980). In addition, Hinton (1981) found a gradual decrease from the Archaic to the Mississippian in the size of the temporomandibular joint, which he relates to a gradual reduction in functional stress related to diet.

As previously noted, social ranking increases with the development of chiefdoms. However, in one of the most comprehensive studies to date of the biological effects of status on Mississippian population in Tennessee, Parham (1982) consistently found no significant differences between status groups at Toqua despite the use of health indicators including stature, porotic hyperostosis, cribra orbitalia, periostitis, tumors, and arthritis, as well as analysis of life tables. Later research on three Dallas sites by Betsinger (2002) followed a modified version of Parham's methodology and included intersite comparisons. Her comparisons within sites and across sites (that is, sites combined) demonstrate that, in general, higher-status individuals interred in mounds were less stressed than those in lower-status nonmound burials.

Central and Western Tennessee

The sites in this region are found predominantly in the Nashville Basin, between the eastern and western portions of Tennessee. Aside from two Archaic sites—Robison and Anderson—most of the sites date to the Mississippian period. The largest and most well studied of these is the Averbuch site (Berryman 1981), but others include Ganier (Ward 1972), Arnold (Ward 1972), West (Wright et al. 1973), and Brown (Boyd et al. 1983).

Although many of the health patterns observed in eastern Tennessee apply to the central region as well, fewer analyses have been completed (Table 5.2). In stature, Mississippian males look similar to their Archaic counterparts, but

Table 5.2. Mean Stature Values and Proportion of Total Population Displaying Various Pathologies at Sites in Central Tennessee

Period		**Stature (cm)**		**Pathology**			
Site	(*N*)	Males (*N*)	Females (*N*)	Anemia (%)	Inf (%)[a]	LEH (%)	Caries/Ind.[b]
Archaic							
Robison					.00		
Anderson		167.0 (7)	153.6 (7)				1.3[c]
Mississippian							
Ganier		167.3 (4)	157.4 (4)				
Arnold		164.6 (2)	160.6 (2)				
West		166.4 (3)	157.1 (3)				
Averbuch		169.2 (87)	158.3 (72)	.39	>.50		
Brown		166.1 (3)	156.8 (3)				

[a] Includes all forms of infection.
[b] Average number of caries occurring per scorable individual.
[c] Caries rate for Eva, Cherry, and Anderson combined.

females are substantially taller. There is no complete study of general periostitis in middle Tennessee populations, but two cases of tuberculosis have been identified in the Late Mississippian, probably related to increasingly dense settlements. While these data may be indicative of tuberculosis, Kelley and Eisenberg (1987) suggest that they might also represent blastomycosis. In other studies, Joerschke (1983) found relatively high rates of arthritis at the Anderson site, whereas Morse (1969) found very low rates of arthritis at the Robinson site. In dental pathology, Archaic populations display high rates of attrition and low dental caries rates. Later groups tend to suffer declining oral health because of a softer, more cariogenic diet.

Northern Alabama

Northern Alabama is an area of rich archaeological tradition of skeletal populations, but information provided in the past was minimal and often incorrect. To help correct this, more than 1,600 individuals have been examined to date, representing six sites (Jacobi 1997, 2000), and their data provide what we know about the health before and after agriculture became important in the region.

Overall, the health of the prehistoric populations along the Tennessee River decreased through time. Infection, mostly general periostitis and osteomyelitis, was found in 24.6 percent of the entire Archaic stage population (*N*=321), but the presence of infection increases to 27.4 percent in the Mississippian (*N*=503). Although the rate of general periostitis slightly increases through time, from 19.94 percent to 23.1 percent, osteomyelitis decreases from 3.7 percent to 1.9 percent. Treponemal infection was almost nonexistent in the

Archaic, with a rate of only 0.3 percent (1 individual out of 321). However, it increases to 1.6 percent in the entire Mississippian population (11 individuals out of 693). Tuberculosis was found in only 1 individual in this entire data set, and this individual was of the Mississippian period population. The occurrence of tumors decreases through time, with the Archaic and Mississippian populations having frequencies of 6.2 percent and 3.8 percent, respectively.

Dental caries and abscesses, as expected, occurred widely in the Archaic and Mississippian, and these problems became more frequent with increased agricultural activities. Only 7.5 percent of Archaic individuals had evidence of dental disease, while the Mississippian population exhibited almost double the amount of dental caries and abscesses (14.7 percent).

Porotic hyperostosis and cribra orbitalia are surprisingly stable at about 15 percent through time. Because this frequency would be expected to be much higher in the Mississippian population, individuals may still have been supplementing their diets with wild food sources. Stature is another health indicator that often reflects dietary quality. In this regard, males increased in stature by about 3 centimeters from the Archaic to Mississippian times (the Archaic mean is 168.38 centimeters, N=56; and the Mississippian mean is 171.84 centimeters, N=35). Females increased in stature by about 3 centimeters (the Archaic mean is 160.84 centimeters, N=35; and the Mississippian mean is 162.13 centimeters, N=25).

Two sites in the Guntersville Basin provide information about health patterns during the period when intensification was occurring. The Widows Creek site has been carbon dated to the Late Woodland (Norton 2004). About one mile down the river and three hundred years later is the Williams Landing site, which has been carbon dated to the Early Mississippian (Norton 2004). Although sample sizes are small, the cultural and botanical assemblage suggests that these populations were in the process of increasing their dependence on cultigens. Widows Creek has a total of twenty-six burials, most of which are older children and adults (Norton 2004). Williams Landing, in contrast, has forty-three individuals, with no infants and very few children (Colonias 2002). Mean stature increases nearly two centimeters with time between the two series, but another indicator of childhood health, linear enamel hypoplasias, is actually significantly higher in the Woodland than in the Mississippian period. Most defects were slight; this may indicate more frequent, but less acute, stress episodes, perhaps associated with periods such as the winter famine. Infection and dental caries rates fall into the predicted patterns. Both time periods exhibit evidence of treponematosis, but only the Mississippian group displays signs of tuberculosis.

Pickwick Basin populations demonstrate changes in activity patterns associated with subsistence change from the Archaic period to the Mississippian.

Midshaft circumference and asymmetry increased significantly for all six sites through time. Among males during the Mississippian period, this might be related to use of the bow rather than the atlatl. In females, the asymmetry was probably related to their greater role in subsistence processing, specifically, the pummeling of maize with large wooden pestles (Bridges 1989). Vertebral osteoarthritis decreased from the Archaic to the Mississippian, presumably reflecting a less active lifestyle (Bridges 1994).

In another investigation of lifeways in the Pickwick Basin, Smith (1996) has observed very high rates of interpersonal conflict in both the Archaic and Mississippian periods. Shields (2003) conducted a study at the Archaic Mulberry site (1Ct27) in which he set up a model to differentiate interpersonal from accidental trauma. Although he found that 41.7 percent (n=29) of the population had injuries, he could not identify any injuries that were unquestionably associated with conflict.

Tennessee-Tombigbee Waterway

This region of northeastern Mississippi and northwestern Alabama has Moundville, with its 2,000 burials, as its most famous site. In addition, cultural resource management projects in the 1970s and 1980s produced a good corpus of small but well-analyzed skeletal samples. The sites involved include the Late Woodland populations from Shell Bluff (Rose 1980), White Springs (Rose 1980), Cofferdam (C. A. Williams 1994a), Bynum (Newman 1951), and 1Pi61 (Hill 1981). Mississippian period sites investigated are 1Pi33 (Hill 1981), Lubbub (Powell 1983), Moundville (Powell 1988, 1998), Kellogg Village (Sims et al. 1992; Danforth 1996), and Tibbee Creek (Larsen 1981). When the results from these samples are considered, as may be observed in Table 5.3, the only solid pattern to emerge among the health indicators is that the rate of dental caries increases over time. Anemia and infection rates may be somewhat lower in the Mississippian, but this may reflect interobserver differences in scoring. The stature data are too few for the Late Woodland to permit any conclusions to be drawn. Linear enamel hypoplasias were observed in only a few populations. Rates and ages-at-formation largely remained the same—50 percent of individuals are affected at Cofferdam, Kellogg, and Moundville. If hypoplasias are associated with weaning, the timing does not appear to have changed (C. A. Williams 1994a). However, the proportion of moderate and severe episodes at Moundville is greater than at either of the small sites. The rate of dental caries in this region does not increase markedly with the adoption of agriculture.

Overall, these data do not follow the expected pattern of worsening health following plant domestication (Cohen and Armelagos 1984). It does fit a model, however, developed to explain archaeological findings in the Gainesville Lake

Table 5.3. Mean Stature Values and Proportion of Total Population Displaying Various Pathologies at Sites in Tennessee-Tombigbee Waterway

Period		**Stature (cm)**		**Pathology**			
Site	(*N*)	Males (*N*)	Females (*N*)	Anemia (%)	Inf (%)[a]	LEH (%)	Caries/Ind.[b]
Late Woodland							
Shell Bluff	27			.30	.67		2.1
White Springs	28			.00	.17		
Cofferdam	24		148.0 (1)	.68	.50	.50	0.5
1Pi61	33	172	159	.05	.83		#[c]
Bynum	21	167.6 (2)		.11	.17		1.4
Mississippian							
1Pi33	64	163	160	.18	.51		##[c]
Kellogg Village	43	168.5 (5)	157.6 (5)	.40	.45	.68	1.8
Tibbee Creek	13	174.0 (2)	157.8 (2)	.41	.18		0.7
Lubbub	28			.08	.10		1.9
Moundville	564	168.6 (52)	157.5 (50)	.04	.27	.54	2.6

[a] Includes all forms of infection.

[b] Average number of caries occurring per scorable individual.

[c] # = .09 caries/tooth; ## = .16 caries/tooth.

area (Jenkins 1982). There, Hill (1981) observed that health was worse before the widespread adoption of agriculture, as evidenced by the higher rates of anemia and infection in the Late Woodland, and attributes this to rising population densities during the period. Faunal analysis provides further support for this explanation. Scott (1983) noted that individuals during the Late Woodland moved from first-line resources (namely, deer) to smaller, less efficient prey (such as rabbits). The cause of the increase in population is debated, although Rafferty (1994) has suggested that it was related to greater sedentism. Thus, it may be said that health improved during the Mississippian with the adoption of a subsistence strategy able to provide for the local population levels.

The extent to which everyone in this region consumed maize is debated. The small sites are generally assumed to have had a somewhat different diet from the large mounded centers because they could more easily supplement diet with wild resources. This question has been investigated in two ways. One study looked at tooth wear at a single mounded site and a number of hamlet sites. Using evironmental scanning electron microscopy (ESEM) to evaluate microwear, Fredericksen (2000) observed no difference between wear patterns at the single mounded center of Lyon's Bluff compared to those of the small villages around it. He found that while both had scratches and pitting, suggesting a somewhat gritty diet, there was no difference in patterns between the mounded and nonmounded sites

Isotope values are another way to directly evaluate diet, but there are only a few studies from this region. Hogue and Peacock (1995) found a mean ^{13}C value of -14.9 at the Late Mississippian farming hamlet called South Farm

(*N*=3), suggesting a diet of about 34 percent maize, at a site at which exploitation of wild resources would still be feasible. Surprisingly, Schoeninger and Schurr (1998) found a similar value of -15.0±4.0 at Moundville. Once their values were adjusted for the offset of a 25 percent protein diet (mostly from fish), the proportion of the diet from maize rises to 65 percent in the early periods of occupation at the site. Reliance on domesticates at the site fell off dramatically in the later occupation periods. No differences by sex or status were found in maize consumption at Moundville. In contrast, ^{13}C values of -12.2 and -13.2 were found for two individuals at Lyon's Bluff, a single mound site in the region (Hogue 2000). These values suggest that inhabitants at Moundville did consume a higher proportion of maize in their diet than did those at farmsteads.

Mississippi Delta

The floodplain of the delta of the Mississippi and Yazoo rivers encompasses northwestern Mississippi, from Vicksburg up into the southwestern corner of Tennessee. Despite the high population levels that must have been present in this extremely resource-abundant area, relatively few osteological studies have been published. Three well-analyzed sites date to the Late Woodland/Early Mississippian. The largest among these is Austin (Ross-Stallings 1989, 1994); the other two sites are the small centers of Bonds (Ross-Stallings 1989, 1994; Danforth et al. 2007) and Womack Mounds (Heckel 1966). The more numerous Late Mississippian sites include a large set of remains from the large mounded community of Lake George (Egnatz 1983; Trisi n.d.). Other sites, varying widely in sample size, are Humber (Mitchell 1975; Danforth et al. 2007), Ferguson/Truly (Danforth 2004), Mangum (Dailey 1974; Penton 1995), Chucalissa (Nash and Gates 1962; Robinson 1976; Lahren and Berryman 1984), and Chickasaw Bayou/King's Crossing (Danforth 2004). The results of these analyses are given in Table 5.4. In the Mississippi Delta, stature appears to have been stable among males but increased with time in females. Femoral midshaft circumference seems to follow a somewhat similar pattern, as it increased from 91 to 93 millimeters in males and from 81 to 85 millimeters in females (Ross-Stallings 1994). The other health indicators that were observed display quite high frequencies in both time periods; thus, they did not change markedly with the adoption of agriculture.

Treponematosis has been observed in at least three delta sites. Two, Lake George and Winterville, are Mississippian; they are among the largest mounded sites in the region. Three cases are also reported in the Late Woodland Austin population, although some elements of the site may be Early Mississippian (Ross-Stallings 1989, 1994). Population density was likely higher than that at the typical Woodland community, and individuals display a higher than expected level of periostitis.

Table 5.4. Mean Stature Values and Proportion of Total Population Displaying Various Pathologies at Sites in Mississippi Delta

Period		**Stature (cm)**		**Pathology**			
Site	(*N*)	Males (*N*)	Females (*N*)	Anemia (%)	Inf (%)[a]	LEH (%)	Caries/Ind.[b]
Late Woodland							
Austin	>160	169.5	156.2	.50		.82	
Bonds	15	169.5 (3)	161.2 (4)	.09	.20	.44	0.3 [c]
Womack	26	170.4 (2)					[d]
Late Mississippian							
Chickasaw Bayou	53			.19		.33	0.5
Ferguson/Truly	20			.14		.50	1.2
Humber	40	168.9 (4)	160.0 (4)	.51	.44	.50	2.9
Lake George	185	171.5 (9)	164.8 (6)		>.12		
Mangum	68	170.0 (12)	157.5 (11)	.12	.27	.69	2.3
Chucalissa	162	165.99 (26)	154.0 (31)	.32	.36		

[a] Includes all forms of infection.
[b] Average number of caries occurring per scorable individual.
[c] Eight teeth additionally lost antemortem (Danforth et al. 2007).
[d] "Few" caries reported (Heckel 1966).

Even though few data are available about disease and nutrition for the Mississippi Delta, the patterns that are seen parallel those of northeastern Mississippi and northwestern Alabama. Health does not seem to have suffered with Mississippianization, possibly because maize is very rare in the botanical assemblages of the lower Mississippi Valley before 800 BP (Fritz and Kidder 1993). Rose and coworkers (1984) have argued that populations initially adopted maize not as a staple during the Early Mississippian but for ritual purposes. An increase in dental caries and infection, which they related to settlement density, may also reflect an increased reliance on indigenous starchy seed crops, such as knotweed and maygrass. Whether this model should be considered for the Delta is debatable. Only one comprehensive flotation study appears to have been carried out in the Delta region; Scarry (1993:6–30) at Rock Levee concluded that the inhabitants were more reliant on maize than their counterparts to the south were, but not as reliant as those to the north.

Gulf Coast

The Gulf Coast region discussed here, which includes both Alabama and Mississippi, encompasses a hundred-mile stretch of marshy brackish water with many bayous and two large bays, the Mobile and Pascagoula. The potential of the coast in terms of subsistence opportunities would seem to have been quite high, with a broad mix of marine and riverine resources, both faunal and floral, available. There is considerable controversy, however, in terms of how energy-efficient exploitation of the coastal resources would have been. Lewis (1988)

has argued that the time and effort necessary to gather the plant products or catch the marine animals would have made these food items less attractive than the deer and nuts only a few miles inland. Thus, coastal foods would have been utilized most likely on a seasonal basis.

The role of maize for coastal populations during the Mississippian is controversial. Many researchers, including Curren (1976) and Knight (1984), believe that the soils of the area are simply too poor to support horticulture for full-time residency. As a result, the region never experienced the other changes associated with domestication, such as sedentism, ranking, and population density; instead, local sites remained seasonal extraction camps. Recently, however, Blitz and Mann (2000) have suggested that areas of the coast, especially around deltas and small bayous, could indeed support larger communities. As evidence, they offer the fact that there are mounded sites at most such locations. Furthermore, they argue that maize horticulture is present.

Only a few skeletal series have been recovered and analyzed from the coastal region. The only Woodland site of any size is the Harvey site (22HR534) in Biloxi, Mississippi. There, some thirteen individuals were excavated, but unfortunately the archaeological context is of questionable quality, requiring that the remains be analyzed much like those of an ossuary. Most researchers do agree that the remains date to the Early Woodland, however (Blitz and Mann 2000). Several small populations excavated in shell mounds in the Mobile Bay region have been evaluated. They include Andrew's Place (1BA1) (Newman 1960; Danforth 2003), Copeland's Landing (Newman 1960; Danforth 2003), and Pine Log Creek (Danforth 2003). The dating of these remains is not solid either, but most ceramic analysis is supportive of the Mississippian period (Wimberly 1960), with Pine Log Creek possibly extending into the protohistoric. Some of these sites, most likely Andrew's Place, show ceramic ties to Moundville (Gardner 2004).

Although these few populations offer less-than-ideal samples from which to draw conclusions, a few trends do appear to be evident (Table 5.5). Overall, the residents of the Woodland site appear to have been well adapted to their at least part-time coastal environment. Their Mississippian counterparts are of about the same stature and share equally low rates of anemia. Rates of enamel hypoplasia have gone up, but even more prominent is the increase in the level of infection observed. Several of the cases suggest that the cause of the lesions may be treponemal. At Andrew's Place, two sets of tibiae exhibit anterior bowing to some degree. Copeland's Landing also has one skeleton with lesions around the nasal region that are suggestive of treponematosis. Newman (1960) indicated that another individual in the series had syphilis, but the only evidence for this conclusion was heavy periostitis on two fragments of tibia and fibula. These levels of infection would be supportive of higher settlement den-

Table 5.5. Mean Stature Values and Proportion of Total Population Displaying Various Pathologies at Sites on Gulf Coast

Period		**Stature (cm)**		**Pathology**			
Site	(*N*)	Males (*N*)	Females (*N*)	Anemia (%)	Inf (%)[a]	LEH (%)	Caries/Ind.[b]
Early Woodland							
Harvey	13	168.5 (4)	162.5 (2)	.09	.25	.00	0
Mississippian							
Andrew's Place	9	170.5 (2)	157.1 (3)	.20	.75	.50	0
Copeland's Landing	18	167.4 (5)	159.6 (6)	.00	.55	.50	0
Pine Log Creek	>12	169.0 (1)		.17	.00	.55	0

[a] Includes all forms of infection.

[b] Average number of caries occurring per scorable individual.

sity than had been present in earlier times, and thus the population of the region in its entirety was more likely to have been reliant on cultigens; however, botanical evidence supporting this conclusion has not yet been found. Dental caries rates at these sites are no greater than at Harvey, although it should be noted that tooth attrition was very high, likely from the ingestion of fish bone, sand, and other abrasive substances found locally.

Discussion

Overall, the patterns of subsistence change in the mid-central South follow those seen in much of the Eastern Woodlands of North America. Populations in the region began to show signs of sedentism as they intensified reliance on nuts, most commonly acorns and hickory, accompanied by domestication involving many of the native grasses, including maygrass and goosefoot. By the Early Mississippian, however, gardening of squashes and, more important, maize had taken over as the staple crops. Similarly, the social effects of ranking were also highly evident. Large mounded centers became common, as did indicators of ascribed status. Suggestions of the presence of elites could also be found in burials, housing, food consumption, and possession of exotic goods.

Although the traditional transition to horticulture is generally observable in the evidence for political and economic systems of the region, the traditional effects on health are not as consistently found. About the only change that is strongly present is the expected increase in dental pathology with the increased consumption of carbohydrates. Growth disruptions, which should presumably become more frequent with the decreased nutritional value of the already more precarious food sources, do not show a regionwide pattern. The frequency of anemia surprisingly does not seem to increase, instead holding steady at low to medium rates in most groups. In fact, rates appear to decrease in frequency over time in the Tennessee-Tombigbee Valley, and this difference

cannot be attributed to interobserver error, because a single researcher (Hill 1981) was involved. Stature, representing a cumulative indicator of childhood health experiences, is constant in most areas and may even increase at some sites in Tennessee with the shift to domestication.

Infectious lesions show a more complicated pattern in the region. Periostitis and other nonspecific reactions are highly variable in their rates of occurrences, perhaps reflecting small sample sizes and interobserver error. However, the first instances of tuberculosis and treponematosis occurred during the Mississippian, supporting the presumed link between these syndromes and population density as well as proximity to Moundville.

Conclusions

Thus, a variety of patterns can be seen within the south-central United States as the gradual transition to agriculture was made, from the hunting-gathering band-level societies that dominated the Archaic period to the horticulturally based chiefdoms that characterized the Mississippian period. The one health indicator that remains unsurprisingly consistent across the river valleys is the increase in dental pathology, namely, caries and abscesses. Within eastern Tennessee, stature and bone robusticity were stable, but tooth size decreased markedly. Studies have shown that the anticipated status differences in health that would result from ranking are not evident. Because fewer studies have been conducted in western Tennessee, there are fewer data available for that region. However, these studies show that stature for males remained stable but increased for females with the domestication of plants. Infection rates, particularly for diseases such as tuberculosis, also seem to have increased.

In northern Alabama, stature is seen to have risen in both males and females, a change paralleled by general bone robusticity. Arthritis rates decrease with domestication, but periostitis and osteomyelitis rates do not change substantially. Treponemal disease did increase, but the prevalence of this disease remained low. One unanticipated pattern among the health markers observed in this region is that trauma actually decreased dramatically, despite archaeological evidence for more-prevalent warfare, as seen in the construction of centers surrounded by palisades and moats. As in eastern Tennessee, the health data from the Tombigbee-Tennessee River region show no strong differences associated with status between the inhabitants of Moundville and the small surrounding hamlets. In fact, the trend in the data shows better health with horticulture, as indicated by lower rates of anemia and infection. Enamel hypoplasia rates, however, remain relatively stable over time.

Farther south, on the Gulf Coast of Alabama and Mississippi, a more complex situation emerges, since the specific nature of the substance base there

is controversial. Although many health characteristics, including stature and enamel hypoplasia frequencies, remained unchanged with the arrival of the Mississippian period, dental caries levels increased. Even more striking are the patterns of infection seen, despite the anticipated low population densities. To the west in the Mississippi Delta, the health patterns that could be observed resemble those of northern Alabama: male stature was stable, but female stature increased somewhat. Bone robusticity was also greater over time, and treponemal disease made its first appearance with the adoption of domesticated plants.

In summary, with the exception of more and varied infectious disease, our major conclusion is that the overall health of the prehistoric inhabitants of Alabama, Tennessee, and Mississippi was not severely affected by the adoption of agriculture over a thousand years ago.

Acknowledgments

We would like to thank Jay Johnson and Ed Jackson for their suggestions and comments. We dedicate this chapter to the memory of Charlotte Ann Williams.

6

From Early Village to Regional Center in Mesoamerica

An Investigation of Lifestyles and Health

LOURDES MÁRQUEZ MORFÍN AND REBECCA STOREY

Mesoamerica, comprising most of Mexico and northern Central America, is known as one of the world's "cradles" of domesticated crops (particularly maize and squash); of sedentism and increasing population density; of social complexity; and ultimately of civilization.

The archaeological record of nomadic preagricultural foragers is poor. Evidence comes from a variety of areas, but most sites are poorly documented. A variety of adaptations are represented—some coastal, some in highland valleys—resulting in differing lifestyles, diet, and health. The sites represent temporary encampments, and skeletal samples are small and often poorly analyzed. Thus, it is difficult to document the effects of the transition to agriculture before 3500 BP.

In contrast, early settled farming villages and hamlets dated after 3500 BP are more common and have been more thoroughly investigated, and skeletal samples are large enough to permit analysis of lifestyle. A thousand years later, some of these hamlets/villages grew to become centers with monumental architecture, social stratification, and links to other, distant, centers.

In this chapter, we compare rates of stress markers in skeletons from five sites spanning the transition from small hamlets/villages to larger, more densely populated villages/regional centers. The skeletal samples representing initial settlement with agriculture are Tlatilco (Mexico), Cuello and K'axob (Belize) and Copan (Honduras). Later regional centers and larger villages include Cuello and K'axob plus Cuicuilco (Mexico). Most of the collections are poorly preserved, and juvenile skeletons are generally underrepresented. Not all individuals could be scored for all pathological indicators, so missing data and small sample sizes affect quantitative analyses.

For the sites Tlatilco, Cuicuilco, Copan, and K'axob, the authors coded the skeletons the same way for pathologies, so these are comparable. For the site of Cuello, we used available published information and believe that the scoring of pathologies for all samples is very similar. The very detailed osteological and pathological information provided by the Sauls (1991 and 1997) on Cuello

allowed us to divide the sample into comparable age-sex categories for valid comparisons with the other sites.

For aging and sexing, standard techniques (Buikstra and Ubelaker 1994) were employed. Adults are categorized as young (approximately 15–30 years old at death), middle (30–50 years old), and older (over 50 years old). Juveniles were assigned to three categories: 1–4, 5–9, and 10–14 years old.

The pathologies discussed here are primarily nonspecific and chronic indicators. We describe periosteal reactions (PR), especially on the tibia; linear enamel hypoplasias (LEH); porotic hyperostosis (PH); and dental caries, abscesses, and antemortem tooth loss (AMTL). Other possible indicators of health and lifestyle, such as arthritis and trauma, are described when available. Porotic hyperostosis and linear enamel hypoplasias are indicative of severe morbidity during childhood, while dental pathologies reflect diet and hygiene during the adult years. Periosteal reactions can occur at any age and are indicative of both the immunological competence of an individual and general hygienic conditions for a population.

The Agricultural Villages

The five skeletal samples represent both the lowlands and the highlands of Mesoamerica. Their domesticates and general way of life are similar, but one difference is climate. Tlatilco and Cuicuilco are in arid highlands; Cuello, Copan and K'axob are in hot, humid lowlands. In Mesoamerica, related but different complex societies were characteristic of the highlands and lowlands. Of these samples, the Tlatilco sample is the largest and best preserved. Extensive excavations from these early villages are available to allow reconstruction of daily life and health.

Tlatilco may have had regional prominence between circa 3400 BP and 2900 BP. The site was attractive to early farmers because it had rich soils and abundant resources from its proximity to Lake Texcoco (Márquez et al. 2002). The people collected fish, small rodents, deer, peccaries, rabbits, and a great variety of birds. They cultivated maize, squash, beans, and chiles, but probably wild resources remained important.

Tlatilco provides a large skeletal sample, of which 343 of the best-preserved individuals are included here. The social organization of the village had some internal ranking but was apparently a continuum, not a set of distinct statuses. We would not expect access to resources to be highly structured by status differences or gender, but females may have been more involved with the horticulture and males with foraging for wild resources. At Tlatilco, both sexes and older subadults appear to have been physically active.

Many characteristics of Tlatilco in subsistence, labor, and ranking are also

apparent at the other early villages. K'axob is an example of a village in the lowlands (McAnany 2004) with good soils and the protein resources available from the nearby Pulltrouser Swamp. Settlement began circa 2800 BP. K'axob appears to have been quite small during this time and fairly egalitarian, with only domestic residences. Only twelve burials were recovered.

Cuello (Hammond 1991) was founded earlier (circa 3200 BP) and became a larger and richer village at an earlier date than nearby K'axob. Until about 2400 BP, excavation yielded only modest domestic residences, but there was again evidence of only modest status differences. Fifty-five individuals were recovered from these early residences.

Copan, which provided a sample of eighty-nine individuals, is less well understood (Fash 2001), as the size of the early village is unknown. All the individuals were interred in one cobblestone platform/residence, which may be only part of this early settlement. These individuals, like those of K'axob, Tlatilco, and Cuello, represent the pioneering agricultural peoples in these areas.

Early Centers/Larger Villages

Cuicuilco, in the southeastern sector of the Basin of Mexico and close to Lake Xochimilco, began as a village very similar to the others, but by 2300 BP, Cuicuilco had probably become a center with a population between five and ten thousand people. It appears to have been the most important site in the basin at that time.

Shortly afterward, Cuicuilco reached its largest size, its population estimated at perhaps forty thousand in an area of 400 hectares; it was a center and controller of other minor settlements. After a volcanic eruption, Cuicuilco lost both population and regional power but continued for a time until covered completely by lava.

Cuicuilco is considered a complex chiefdom with a permanent elite, supported by intensive agriculture (probably with irrigation canals), more craft specialization, and long-distance exchange. The burials of Cuicuilco differ from those of Tlatilco. Burial furnishings appear to be more linked to hierarchical differences. Some burials are in obviously ceremonial locations. The skeletal sample comprises 119 individuals, all from burials dated from about 2600 to 2150 BP, at the height of Cuicuilco's power.

Cuello, from 2400 to 1750 BP, seems to be larger and wealthier than nearby K'axob at the same time. There are rich burials and evidence of more structured social differences. But perhaps more important is that the area was transformed from residential patio to open ceremonial platform, with ritual mass burials and even a stone monument (stela). The site produced 111 burials.

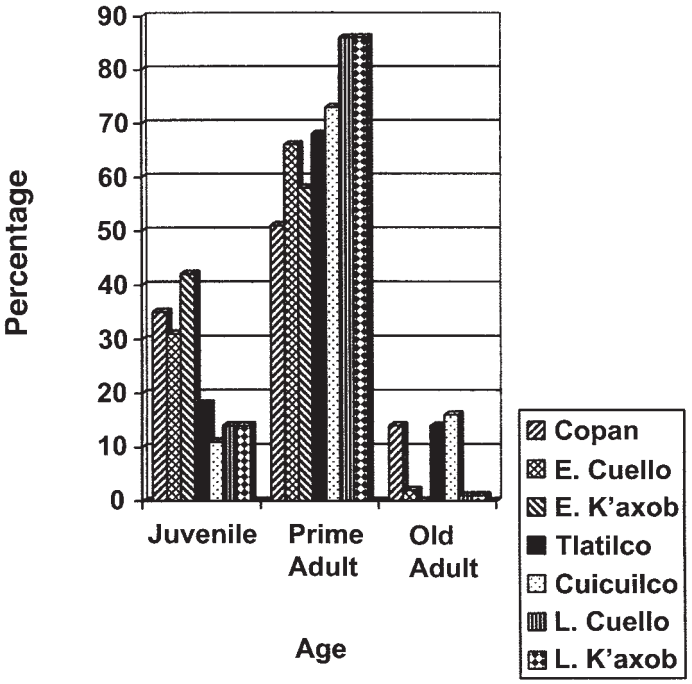

Figure 6.1. Age distributions in Mesoamerican cemeteries.

K'axob became larger circa 2400–1750 BP but appears to have remained an autonomous village. The nature of the interaction between K'axob and larger nearby sites, such as Cuello, is unclear (McAnany 2004). There is evidence of differential statuses that become more marked and structured through time. There is also evidence of domestic residences being transformed into a more ceremonial function as well. The later village provided a sample of eighty-six individuals.

Comparison of the Samples

The skeletal samples are divided into two groups. The early sample represents the initial agricultural settlements and includes early K'axob, early Cuello, Copan, and Tlatilco. The late sample comes from larger and more complex settlements, at which evidence of social stratification appears more defined. This sample comes from late K'axob, late Cuello, and Cuicuilco. The age-at-death distributions for the samples are given in Figure 6.1. We define three age categories: juvenile, prime-age adults (circa 20 to 50 years old), and old adults (50+ years old). It is immediately apparent that the distributions vary,

resulting in the underrepresentation of juveniles in most samples and perhaps of older adults as well.

Heterogeneity in populations makes it difficult to compare the prevalence of disease (Waldron 1994). One needs a way to control for the varying age structures and come up with a summary statistic that will allow unbiased comparison of disease prevalence between two populations (Waldron 1994).

A second hurdle comes from the fact that any skeletal sample is a mortality sample. One must be careful about how health in the skeletons relates to the living population that produced them. If a paleopathological indicator contributes directly toward death, then obviously, the prevalence in the skeletons is likely to be greater than its prevalence among the living, depending on the case fatality rate (Waldron 1994). If an indicator does not contribute directly to death, then the prevalence within skeletons most probably reflects the prevalence in the living population. The nonspecific indicators employed here are of morbidity, not direct causes of death, so it is possible to compare skeletal prevalences.

Direct standardization involves using the same standard population numbers for each age group in each population. This number is multiplied by the age-specific prevalence of the skeletal sample to determine the number of cases that would be present in the standard population if it had the same rates as the skeletal population. One must use a reasonable standard population and use the same population in each comparison. The total number of expected cases is then totaled for each population. When total expected cases are compared between two samples, the resulting ratio, called the standardized rate ratio (SRR), provides a clearly interpretable number contrasting true prevalence between two samples, not biased by age composition differences between the samples (Waldron 1994).

The standard population employed here is an artificial one formed from a combined skeletal sample used for other direct standardization comparisons (Storey and Márquez 2003). In this standard population, there are 185 juveniles, 91 prime-age adults, and 143 old adults, a distribution not affected by either juvenile or old adult underrepresentation.

Table 6.1 compares age-specific rates for three health indicators: tibial infection, linear enamel hypoplasia, and porotic hyperostosis. Small sample sizes for the lowland samples are the result of poor skeletal preservation. The Cuello sample was not assessed in a comparable way for tibial infection, as juveniles were not scored and adult individuals were not discussed by age. However, Saul and Saul (1997: 38) indicate that tibial infection was very common at Cuello, with only 25 percent having normal tibias and 75 percent exhibiting pathology in the early period. That suggests that the incidence of tibial infection at Cuello is probably very similar to that of Tlatilco.

Table 6.1. Age-Specific Rates for Nonspecific Health Indicators in the Early Samples

	Age-Specific Rates			
Condition/ Age Class	Copan Aff./Obs. (%)	Cuello Aff./Obs. (%)	Tlatilco Aff.Obs. (%)	K'axob Aff./Obs. (%)
Tibial Infection				
Juveniles	2/3 (.67)	NA	23/40 (.58)	1/2 (.50)
Prime adults	3/15 (.20)	NA	116/181 (.64)	1/2 (.50)
Old adults	0/6	NA	29/40 (.73)	0/0
Linear Enamel Hypoplasia				
Juveniles	18/20 (.90)	6/11 (.55)	9/17 (.53)	3/4 (.75)
Prime adults	23/24 (.96)	13/21 (.62)	55/120 (.46)	3/3 (1.00)
Old adults	6/8 (.75)	0/1	7/25 (.28)	0/0
Porotic Hyperostosis				
Juveniles	3/11 (.27)	0/0	5/54 (.09)	1/2 (.50)
Prime adults	5/16 (.31)	0/4	20/174 (.11)	1/2 (.50)
Old adults	1/6 (.17)	0/4	5/41 (.12)	0/0

Note: Aff. = number of affected individuals; Obs. = number of observable individuals; % = percentage of individuals affected.

Table 6.2. Direct Standardization Ratios in the Early Samples

Comparison	Standardized Rate Ratio
Tibial Infection	
Tlatilco/K'axob	269.9/138.0 = 1.96
Tlatilco/Copan	269.6/142.2 = 1.90
Copan/K'axob	142.2/138.0 = 1.03
Linear Enamel Hypoplasia	
Copan/Cuello	361.1/158.2 = 2.28
Copan/Tlatilco	361.1/180.0 = 2.01
Copan/K'axob	361.1/229.8 = 1.57
K'axob/Cuello	229.8/158.2 = 1.45
K'axob/Tlatilco	229.8/180.0 = 1.28
Tlatilco/Cuello	180.0/158.2 = 1.14
Porotic Hyperostosis	
K'axob/Tlatilco	138.0/44.4 = 3.11
Copan/Tlatilco	102.5/44.4 = 2.31
K'axob/Copan	138.0/102.5 = 1.35

Comparisons of the SRRs for the early samples are presented in Table 6.2, in descending order of prevalence. For tibial infection, Tlatilco and probably Cuello have almost twice the prevalence, whereas Copan and K'axob are just about equal. For linear enamel hypoplasia, Copan has the highest prevalence, while Cuello and Tlatilco are similar and much less afflicted. Porotic hyperostosis presents a different pattern. The number of expected cases is generally low for all samples, and there are none for Cuello, but Tlatilco is notable for its low age-specific rates.

Table 6.3. Age-Specific Rates for Nonspecific Health Indicators in the Late Samples

	Age-Specific Rates		
Condition/ Age Class	Cuicuilco Aff./Obs. (%)	Cuello Aff.Obs. (%)	K'axob Aff./Obs. (%)
Tibial Infection			
Juveniles	4/10 (.40)	0/1	4/9 (.44)
Prime adults	46/73 (.63)	14/22 (.64)	12/24 (.50)
Old adults	8/15 (.53)	1/1 (1.00)	10/16 (.63)
Linear Enamel Hypoplasia			
Juveniles	3/5 (.60)	3/4 (.75)	6/10 (.60)
Prime adults	27/55 (.49)	27/40 (.68)	17/25 (.68)
Old adults	1/10 (.10)	0/0	21/28 (.75)
Porotic Hyperostosis			
Juveniles	2/11 (.18)	0/4	0/5
Prime adults	18/50 (.36)	2/22 (.09)	6/16 (.38)
Old adults	5/13 (.38)	0/1	1/20 (.05)

Note: Aff. = number of affected individuals; Obs. = number of observable individuals; % = percentage of individuals affected.

Table 6.4. Direct Standardization Ratios in the Late Samples

Comparison	Standarized Rate Ratio
Tibial Infection	
K'axob/Cuello	217.0/201.2 = 1.08
K'axob/Cuicuilco	217.0/207.1 = 1.05
Cuicuilco/Cuello	207.1/201.2 = 1.03
Linear Enamel Hypoplasia	
K'axob/Cuicuilco	280.2/169.9 = 1.6
K'axob/Cuello	280.2/200.7 = 1.4
Cuello/Cuicuilco	200.7/169.9 = 1.2
Porotic Hyperostosis	
Cuicuilco/Cuello	120.4/8.2 = 14.7
K'axob/Cuello	41.8/8.2 = 5.1
Cuicuilco/K'axob	120.4/41.8 = 2.9

For the early period, the three indicators have a distinct pattern. Copan has high incidences of LEH but moderate tibial infection and PH, while Tlatilco and Cuello have high prevalence for tibial infection, moderate for LEH, and very low for PH. K'axob has moderate prevalence for all, but these incidences are based on very small samples. Tlatilco and Cuello were probably larger than Copan and K'axob during this period, which might mean more circulation of disease, more sanitary problems, and more infection. The indicators of childhood stress—LEH and PH—are moderately prevalent in all settlements, which indicates significant morbidity among young children. Diets from agriculture and collecting should have been good, but labor was perhaps inadequate to compensate during times of shortage. Such shortages would have been harder

Table 6.5. Comparison of Direct Standardization Prevalences for Early and Late Samples

Comparison	Standardized Rate Ratio
Tibial Infection	
L. K'axob/Copan	217.0/142.2 = 1.5
L. Cuello/Copan	201.2/142.2 = 1.4
L. K'axob/E. K'axob	217.0/138.0 = 1.6
L. Cuello/E. K'axob	201.2/138.0 = 1.5
Tlatilco/Cuicuilco	269.9/207.1 = 1.3
Tlatilco/L. K'axob	269.9/217.0 = 1.2
Linear Enamel Hypoplasias	
Copan/L. Cuello	361.1/200.7 = 1.8
L. K'axob/E. Cuello	280.2/158.2 = 1.8
L. Cuello/E. Cuello	200.7/158.2 = 1.3
Copan/L. K'axob	361.1/280.2 = 1.3
L. K'axob/E. K'axob	280.2/229.8 = 1.2
E. K'axob/L. Cuello	229.8/200.7 = 1.1
Tlatilco/Cuicuilco	180.0/169.9 = 1.1
Porotic Hyperostosis	
E. K'axob/L. Cuello	138.0/8.2 = 16.8
Copan/L. Cuello	102.5/8.2 = 12.5
E. K'axob/L. K'axob	138.0/41.8 = 3.3
Cuicuilco/Tlatilco	120.4/44.4 = 2.7
Copan/L. K'axob	102.5/41.8 = 2.5

on the weaning-age children, the peak time for morbidity to be reflected on the skeleton.

The three skeletal samples from the later settlements can be compared through the same analytical process as those of the earlier settlements (Tables 6.3 and 6.4). The similarity of the prevalence of tibial infection in all three samples is immediately apparent. The incidence of LEH is variable, with Cuicuilco the lowest and K'axob the highest. Again, PH is generally less prevalent: Cuicuilco has much higher prevalence than the other two sites; Cuello is virtually free of this pathology; and K'axob has five times the prevalence found at nearby Cuello. Cuicuilco has the lowest LEH and highest PH. K'axob has an elevated prevalence of all indicators, perhaps reflecting its more modest size and lesser wealth than the other two centers. The PH differences between Cuello and Cuicuilco are probably the most distinctive, as the lowland environment provided sufficient iron to prevent this pathology but did not particularly buffer children from the stresses that result in LEH.

The next step is to compare prevalence of indicators in early against late samples (Table 6.5). The highland pattern of change over time appears to be different from that of the lowland. For Cuicuilco compared to Tlatilco (both highland sites), there is an increase in prevalence of PH and a slight decrease in tibial infection, while LEH remains about the same. The lowland samples have

a dramatic decrease in PH over time but increases in tibial infection and LEH, revealed especially by the comparisons of K'axob and Cuello through time. The high rate of LEH in Copan and tibial infection at Tlatilco, early samples, are also never matched by any of the later samples.

As all these indicators reflect the synergistic effects of diet, environment, and disease circulation, local differences appear to affect prevalence. One might expect that porotic hyperostosis and linear enamel hypoplasia would show comparable patterns, as both reflect morbidity and stress during childhood. However, these have very different patterns, especially in the lowlands. This must indicate that despite the humidity of the lowland environment, which would be expected to have had problems with infections and parasites, the diet was robust enough to buffer children from developing porotic hyperostosis. By contrast, these potential stresses probably did cause LEH to be common among subadults in the lowlands. Unfortunately, however, the sample numbers for porotic hyperostosis are small, especially for early Cuello and K'axob, so the pattern of decrease may not hold. In the highlands, porotic hyperostosis is definitely more prevalent at Cuicuilco than at Tlatilco, while the prevalence of linear enamel hypoplasia is similar. Thus, whatever buffering had been available from diet at the early village was lost at the early center. The change could reflect an increase in maize in the diet and less availability of high-quality protein for children at Cuicuilco.

Dental Pathologies

Dental pathologies are indicative of adult diet (caries) and hygienic conditions (abscesses). Comparisons are affected by differing age compositions, as caries and loss tend to increase with age. However, the age breakdown of Tlatilco and Cuicuilco is quite similar (see Figure 6.1), so these two sites can be compared on the basis of the percentage of individuals affected. The proportion of teeth with caries in the population, or the caries index, is 14 percent at Cuicuilco but only 9 percent at Tlatilco. However, Tlatilco individuals are missing about 15 percent more teeth than individuals at Cuicuilco. Abscesses are very similar at these two highland sites, with about 3 percent of jaws affected. The caries index, like porotic hyperostosis, probably reflects the greater dependence on maize at Cuicuilco as compared to the earlier village. However, antemortem tooth loss at Tlatilco probably reflects more wear from a diet still largely made up of fibrous and wild foods.

The better preservation of the Basin of Mexico samples, Tlatilco and Cuicuilco, allows comparisons between other skeletal indicators. Trauma can be studied in the form of healed fractures, amputations, and cut wounds. These provide information on risks and interpersonal violence. Even though abun-

dant archaeological evidence indicates the importance of war in pre-Columbian Mesoamerica, the early sites seem to have been less militaristic. For fractures of extremities, Tlatilco had six of the arm (2.3 percent of those that could be scored) and seven of the leg (2.4 percent). Cuicuilco had three arm (2.8 percent) and one leg (1 percent) fracture. These injuries are likely to have been the result of accidents from going about daily tasks. When injuries to head and face are considered, Cuicuilco had only 1 percent of scorable individuals with such injuries, while Tlatilco had almost 7 percent afflicted with nasal injuries but only 1 percent with face and head injuries. Individuals at Tlatilco seem to have experienced slightly more trauma.

For osteoarthritis, around one-third of individuals who could be scored had arthritic involvement in shoulder/elbow and hip/knee in both populations. However, in Cuicuilco, the percentages with hand, wrist, and thoracic involvement are double those of Tlatilco. The greater involvement of hands and wrists may be attributable to greater importance of specialized tasks, such as ceramics and textile weaving. Cuicuilco may reveal the influence of a more specialized economy and of generally more activity than in the early village.

As a last indicator, auditory exostoses were found only in Tlatilco skeletal remains. These are considered to be the result of diving in cold water. Interestingly, while 44 percent of the exotoses were in males, 27 percent were in females, indicating that females also did some diving. By Cuicuilco times, this activity was probably specialized, and Cuicuilco residents did not dive to exploit lake resources.

Summary

Overall, the situation reveals that the burden of morbidity increased through time in pre-Classic Mesoamerica, especially in tibial infection and linear enamel hypoplasia. There are changes in activity patterns that reflect changes in subsistence and economic activities among the people. Dental pathologies seem to indicate at least an increase in caries. All of these changes are linked to a change from small settlements with less inequality and more varied diet to larger, denser settlements with more inequality and more dependence on agricultural products. Of course, the small sample sizes underlying some indicators make these results tentative.

The question of whether there is a true trend within the pre-Classic can be investigated by making some comparisons with later, larger, and more urban populations. Table 6.6 presents SRR comparisons with some later skeletal samples. For the highlands, Tlajinga is from a lower-status compound in the preindustrial city of Teotihuacan, and Cholula, from the later urban center of that name, is a sample of mostly laborers resident there. For the lowlands,

Table 6.6. Comparison of Prevalence by SRR in Highland and Lowland Samples through Time

Region/Comparison	Standardized Rate Ratio
Tibial Infection	
Highlands	
Tlatilco/Tlajinga	269.9/145.1 = 1.9
Tlatilco/Cholula	269.9/360.0 = .75
Cuicuilco/Tlajinga	207.1/145.1 = 1.4
Cuicuilco/Cholula	207.1/360.0 = .58
Lowlands	
L. Cuello/Bacabs Palace	201.2/202.7 = .99
L K'axob/Bacabs Palace	217.0/202.7 = 1.1
Copan/Bacabs Palace	110.7/202.7 = .55
Copan/Jaina	110.7/209.9 = .53
Copan/L. Copan Rural	110.7/292.0 = .38
Linear Enamel Hypoplasia	
Highlands	
Tlatilco/Tlajinga	180.0/372.0 = .48
Tlatilco/Cholula	180.0/126.2 = 1.4
Cuicuilco/Tlajinga	169.9/372.0 = .46
Cuicuilco/Cholula	169.9/126.2 = 1.3
Lowlands	
L. Cuello/Bacabs Palace	200.7/386.0 = .52
L K'axob/Bacabs Palace	280.2/386.0 = .73
Copan/Bacabs Palace	364.0/386.0 = .94
Copan/Jaina	364.0/266.0 = 1.4
Copan/L. Copan Rural	364.0/296.1 = 1.2
Porotic Hyperostosis	
Highlands	
Tlatilco/Tlajinga	44.4/26.9 = 1.7
Tlatilco/Cholula	44.4/53.0 = .84
Cuicuilco/Tlajinga	120.44/26.9 = 4.5
Cuicuilco/Cholula	120.44/53.0 = 2.3
Lowlands	
L. Cuello/Bacabs Palace	8.19/63.2 = .13
L K'axob/Bacabs Palace	41.8/63.2 = .66
Copan/Bacabs Palace	106.2/63.2 = 1.7
Copan/Jaina	106.2/103.4 = 1.03
Copan/L. Copan Rural	106.2/242.2 = .44

there are two samples from later Copan, a thousand years later than the earlier one: Bacabs Palace is from an elite sample, and Copan Rural is a sample of the commoners farming the area. Jaina is an elite Maya site (from the Yucatán Peninsula) that is contemporary with Copan. The calculations using the same standard population are taken from Storey and Márquez 2003.

The trend in porotic hyperostosis in the highlands is that Cuicuilco has the highest prevalence; in the later urban centers, the prevalence of porotic hyperostosis falls. However, in the lowlands, there is a trend toward higher

prevalence through time. For tibial infection, the lowlands have a general pattern of increasing incidence. At most, it remains the moderate incidence that was consistently present there. The highlands pattern again is less clear. The incidence of tibial infection decreases from Tlatilco to Tlajinga but then increases dramatically in the latest site of Cholula. Linear enamel hypoplasia also increases or remains at a high incidence in all highland and lowland later sites, except Cholula which shows a decrease. The lowland sites generally show a greater burden of morbidity through time, whereas the pattern in the highlands is generally one of increase, except for porotic hyperostosis. Residents of a few sites appear to have been able to ameliorate some conditions, resulting in a decrease in the incidence of some pathological indicators.

The agricultural villages and later centers of Mesoamerica consistently have what might be characterized as moderate prevalences of most pathological indicators, indicating that morbidity was common in the daily lives of these people. It is unfortunate that there are no foraging skeletal samples available at this point to permit better contextualization of the time trend present here. Our results indicate that changes in increasing dependence on agricultural products in the diet, larger and denser settlements, and increasing social differentiation seem to lead to generally higher burdens of morbidity, but even the early agricultural villages have incidences of some indicators that are as high as those of later urban centers. Was life better for earlier foragers, or were the arid highlands and hot, humid lowlands of Mesoamerica always difficult places to make a living?

Acknowledgments

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7

Skeletal Biology of the Central Peruvian Coast

Consequences of Changing Population Density and Progressive Dependence on Maize Agriculture

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On the Peruvian coast, population growth and the rise of social complexity preceded dependence on intensive maize agriculture by some two thousand years. This unique cultural trajectory provides an opportunity to study the consequences of increasing population density for human health independently from the consequences of reliance on maize agriculture. Demographic expansion and large-scale monumental construction began on the central coast sometime between four and five thousand years ago (Moseley 1975; Shady et al. 2001). Maize was apparently first cultivated during the Initial period (3400–2900 BP) but had yet to become a staple crop (Pearsall 2003). The large population centers of the Cotton Preceramic period probably thrived on abundant marine resources, augmented with foods produced by means of noncereal agriculture (Moseley 1992a, 1992b; Sandweiss 1996).

The proximity of the steep slopes of the Andes to the narrow coastal expanse of the Sechura desert creates a circumscribed area of remarkable environmental variability in western Peru. In this rugged terrain, microclimates vary within very short distances, and up to twenty different environmental zones can be crossed on foot in a matter of days (Burger 1992: 12). Temperatures and rainfall vary significantly from site to site, along with requisite subsistence practices, pathogens, and parasitic loads.

Prehistoric fishing peoples generally benefited from bountiful marine resources, rich in protein and iron. However, they frequently suffered from intestinal parasites of the genus *Diphyllobothrium,* probably contracted from fish (Reinhard and Urban 2003). *Diphyllobothrium* ova have been documented in Chinchorro mummies (5000–4000 BP) from Chile (Reinhard and Aufderheide 1990), in coprolites from Los Gavilanes (4850–4700 BP) (Patrucco et al. 1983), and in human remains at Chiribaya (AD 600–1476) from southern Peru (Holiday et al. 2003).

With the development of irrigation, people in the lower valleys eventually came to depend more on maize-rich diets, deficient in iron, lysine, and niacin. Heavy parasitic loads in these communities apparently resulted from their freshwater sources being polluted by upstream dwellers (Blom et al. 2005). Intestinal parasites—including pinworm (*Enterobius vermicularis*), giant roundworm (*Ascaris lumbricoides*), and whipworm (*Trichuris trichiura*)—were contracted from conspecifics or hunted animals (Patrucco et al. 1983). High rates of anemia for lowland fishing and farming populations stand in contrast to a virtual lack of this pathology among upland dwellers (Blom et al. 2005; Hrdlička 1914).

Modal subsistence practices changed considerably through prehistoric times on the central coast of Peru. During the Middle Preceramic period (6000–4500 BP) marine resources provided an overwhelming majority of the available calories for coastal villagers (Reitz 1986, 1998, 2001). Trace element and stable isotope analysis of human bones from Paloma indicate probable reliance on fishing to acquire food. The common occurrence of auditory exostoses on Paloma crania suggest that diving and swimming were practiced on a regular basis, especially by males (Benfer 1990).

Although horticulture apparently played a secondary role at Paloma (Weir et al. 1988), Pearsall (2003) has identified eleven cultivated plant taxa from Middle Preceramic sites in the area. The most common was the bottle gourd, valued as a container and later for net floats. Other documented cultigens include four tubers: begonia, *achira,* jicama, and manioc; the cereal quinoa; various cucurbits; peanuts; and *ciruela* (Pearsall 1992, 2003). By the end of the Middle Preceramic, beans had been added to the mix as well. Possibly in response to the introduction of beans, an independent source of protein, the frequency of anemia indicators at Paloma declined steadily through succeeding levels, from 36 percent of crania affected at Level 400 to only 12 percent of crania affected at Level 200, while average individual stature increased (Benfer 1990). Benfer (1984, 1997) has also proposed that cultural adaptations to sedentary life at Paloma developed with time, resulting in a gradual improvement in overall health.

For the subsequent Late (Cotton) Preceramic period (4500–3500 BP), there are clear archaeological indications of increasing population density, the emergence of social hierarchies, and more formalized governance in central Peru (Haas et al. 2004). Faunal analysis (Weir et al. 1988), the stable isotope composition of human bones (Falk et al. 2004; Tykot, Burger, and van der Merwe 2006), and high frequencies of auditory exostoses (Tattersall 1985) all indicate that heavy reliance on marine resources continued through the Late Preceramic and into the Initial period (3400–2900 BP). Nevertheless, the overall subsistence base appears to have become more complex, involving

irrigation-based production of some food plants (Pearsall 2003). Both maize and potatoes were added to the list of cultigens during the Initial period, but neither immediately assumed a staple role (Pearsall 2003; Tykot, Burger, and Van der Merwe 2006; Falk et al. 2004).

It remains uncertain when maize finally became a staple on the central coast. In the highlands, there was very little maize in the human diet even during the subsequent Early Horizon (2900–2200 BP) (Burger and van der Merwe 1990). For the time being, the earliest evidence that maize contributed substantially to the human diet comes from the Villa Salvador and Tablada de Lurín skeletal collections, dating to the Early Intermediate period (Falk et al. 2004).

The Archaeological Setting

Our study is focused on human skeletal collections from archaeological sites located between Río Seco and Río Grande de Asia, an area spanning approximately three hundred kilometers from north to south (Figure 7.1; Table 7.1). These sites are all situated directly on the coast or else in the lower valleys, below where fog oases occur. The nine chronologically sequential skeletal collections utilized in this study span the time frame represented by the Middle Preceramic (6500–5000 BP) through the Middle Horizon (AD 400–1000). These collections vary greatly in size, from only four skeletons from Río Seco and from Chilca 1 to 201 individuals from Paloma. As missing elements result in different sample sizes depending on the indicator being examined, pertinent sample sizes vary from table to table.

Table 7.1. Chronology and Sample Sizes for Skeletal Series Discussed

			Number of Individuals				
Site	Period[a]	Dates[a]	Total	Males	Females	Indt.	Sub.
Paloma	Middle Preceramic	6500–4750 BP	201	44	42	29	86
Chilca One	Middle Preceramic	5150–4750 BP	4	3	1	—	—
Asia Beach	Cotton Preceramic	4350–3000 BP	33	9	11	1	12
Río Seco	Cotton Preceramic	3950–3800 BP	4	2	—	—	2
Cardal	Initial Period	3400–2900 BP	48	16	14	4	14
Tablada de Lurín	Early Intermediate Blanco Sobre Rojo	2200–1900 BP	31	11	16	0	4
Villa Salvador	Early Intermediate Blanco Sobre Rojo	2200–1900 BP	181	64	68	5	44
Huaca Pucllana	Early Intermediate Lima Culture	1800–1300 BP	25	3	22	0	0
Huaca Huallamarca	Middle Horizon–Late Intermediate	1400–1000 BP	78	30	23	2	23

Note: Indt. = adult, sex indeterminate; Sub. = Subadult.

[a] Adapted from Benfer 1990, Vradenburg 2001, and Lanning 1967.

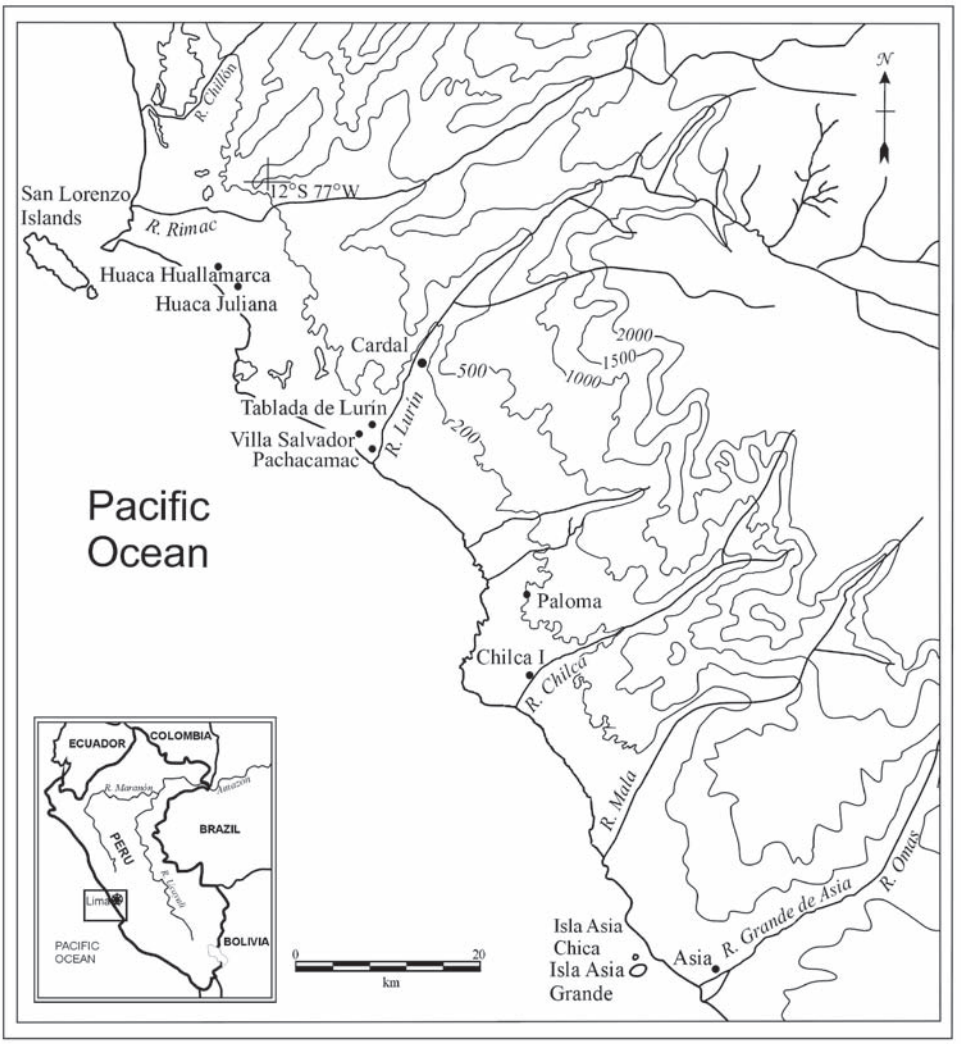

Figure 7.1. Map of study area on the Peruvian Central Coast.

Paloma, a Middle Preceramic period village reliant on fishing and foraging, was located on the northern edge of the Chilca Valley, at 12°30' S, 76°40' W, within 7–8 kilometers of the river and lying 3.5 kilometers east of the coast (Engel 1980; Quilter 1989). Situated on a steep slope at between 200 and 220 meters above sea level, the site is just below the fog oasis today. Three excavated occupation levels contained human skeletal remains: Paloma Level 400 (6500–5200 BP), Paloma Level 300 (5300–5100 BC), and Paloma Level 200 (5100–4700 BP).

A total area of 2,860 square meters has been excavated at Paloma, uncovering evidence of fifty-five simple reed huts and deep middens. Human burials were recovered primarily from below or adjacent to house floors. The skeletal remains of a total of 201 individuals from Paloma were analyzed (Benfer 1990). These bodies were typically flexed, wrapped in mats and placed on their sides in straw-lined pits. Sparse grave goods included grinding stones, beads, shells, and stone tools, offering little to suggest social stratification (Quilter 1989). The number of Paloma residents apparently increased considerably between the time period represented by Level 400 and that represented by Level 300, as suggested by comparison of total house floor areas and the demographic profiles of the respective populations, but thereafter declined slightly (Vradenburg et al. 1997).

The Chilca 1 site lies on the banks of the lower Chilca River, which carries water only a few months of the year. Burials and houses recovered at Chilca 1 are very similar to those found at Paloma. It was the first Middle Preceramic (Archaic) site to yield substantial evidence of cultigens in Frederic Engel's excavations (Engel 1970). The common bean was especially important as a plant protein source (Weir et al. 1988).

The Cotton Preceramic is evidenced by skeletal samples from two sites: Asia Beach (Engel 1963) and Río Seco (Wendt 1963). Asia Beach is a group of mounds located south of Lima at 12°46' S, 76°35' W, some 500 meters from the ocean, on the north bank of the Río Omas. Associated radiocarbon dates suggest that the site was in use from approximately 3300 to 3000 BP (Engel 1963; Weir et al. 1988). The site of Río Seco is located at the river mouth, 87 kilometers north of Lima at 11°20' S, 77°24' W. At both of these loci, bodies were bundled in a tightly flexed position into grass mats and textiles, then buried underneath the floors of structures. Grave goods were few, although some of them were quite elaborate.

Skeletal remains dated to the Initial period come from Cardal, a U-shaped civic ceremonial center occupied between 3500 and 2800 BP (Burger 1987; Burger and Salazar-Burger 1991). Cardal is located one kilometer south of the Río Lurín, within walking distance of both the littoral and the fog oasis. In total, the remains of at least forty-eight individuals were recovered from three distinct proveniences at Cardal: the central pyramid in Sector IIIA, the general residential Sector IIIB, and an area of apparent public architecture in Sector V. Burial ritual was similar to that of the Cotton Preceramic, although greater social inequality is documented by disparities in funerary offerings (Burger 1992).

No skeletal collections dated to the Early Horizon were available for analysis. Therefore, human remains from Villa Salvador (Stothert and Ravines 1977;

Delgado 1992, 1994) and Tablada de Lurín Necropolis (Makowski 1994, 2002), two cemeteries dated to the beginning of the Early Intermediate period, come next in our temporal sequence. Both cemeteries are situated just south of Lima in the arid Tablada de Lurín, which divides the lower Lurín and Rimac valleys. At 12°15' S and 76°56' W, Villa Salvador is four kilometers west and downstream from Tablada de Lurín Necropolis. The majority of individuals in these cemeteries were buried in a seated position facing towards the ocean. Undecorated pots, copper plaques, shell beads, and bone tools were the most common offerings. A few graves contained more elaborate sculpted ceramic vessels or gilded copper objects. Burials at both sites were associated with examples of a local variant of the White-on-Red ceramic tradition (Miramar style) (Patterson 1966; Earle 1972). As interlocking motifs are absent from the decoration of this pottery, Makowski (2002) suggests that all these burials predated the formation of the Lima State at shortly after AD 100.

Huaca Pucllana, also known as Huaca Juliana, became an important administrative and ceremonial center during the florescence of the Lima culture. The site is located in the lower Rimac valley, on what is now General Borgoño Street in the Miraflores district of modern Lima (Flores 1981; Vasquez 1984). Most of the prehistoric structures at the site were built between AD 200 and AD 700, including the main pyramid. We have studied twenty-five skeletons from Huaca Pucllana, most of which are the remains of young females, probably sacrificial victims.

Huaca Huallamarca (12°05' S and 77°02' W), also known as Huaca Pan de Azúcar, is a large pre-Inca pyramid located at Nicolás de Rivera 210 in the San Isidro district of modern Lima. The earliest prehistoric construction at this site, which is only about 100 meters above sea level, was probably contemporaneous with the buildings at Huaca Pucllana, dating to the end of the Early Intermediate period (Ravines 1985: 74). Huaca Huallamarca gained further importance during the Middle Horizon. The majority of burials there are from that later era. Many of the burials were multiple and skeletons were often commingled. Identifiable individuals from Huaca Huallamarca included thirty adult males, twenty-three adult females, two adults of indeterminate sex, and twenty-three subadults.

Diet and Oral Health

The rate of carious infection estimates the dietary importance of starchy carbohydrates and, by extension, the degree of reliance on agriculture, as well as providing evidence as to prevailing methods of food preparation (see for example, C. S. Larsen 1983, 1984; Rose et al. 1984; Turner 1979). Significant

Table 7.2. Frequencies of Carious Lesions and Calculus Accretion

			Teeth with Calculus Accretion			
Site	n[a]	Carious Teeth	Absent	Slight/ Moderate	Severe	Lost Antemortem[b]
Paloma[c]	704	0.0043	NA	NA	NA	0.00
Asia Beach						
Total	398	0.0591	0.32	0.61	0.00	0.27
Male	199	0.0312	0.28	0.68	0.00	0.18
Female	110	0.1900	0.40	0.59	0.00	0.34
Cardal						
Total	335	0.0448	0.25	0.31	0.44	0.11
Male	176	0.0398	0.22	0.33	0.44	0.07
Female	153	0.0522	0.29	0.29	0.42	0.17
Tablada de Lurín						
Total	323	0.0588	0.41	0.56	0.01	0.67
Male	156	0.0577	0.27	0.69	0.09	0.64
Female	113	0.0442	0.57	0.43	0.03	0.68
Villa Salvador						
Total	1,184	0.1942	0.15	0.70	0.14	0.25
Male	520	0.1346	0.14	0.71	0.13	0.22
Female	642	0.2688	0.16	0.69	0.15	0.30
Huaca Pucllana						
Total	332	0.0724	0.22	0.76	0.02	0.24

[a] n = number of permanent teeth analyzed.

[b] Frequencies of teeth lost antemortem computed from the number of tooth sockets present.

[c] Paloma frequencies are based on analysis by Edwards (1984), which included only complete dentitions with no teeth lost antemortem or postmortem; data on calculus are not available.

differences among skeletal samples suggest large-scale shifts in the human diet between the Middle and Cotton Preceramic, as well as between the Initial and Early Intermediate periods (Table 7.2).

The frequency of carious teeth in the Paloma collection is below 1 percent (3 carious teeth out of 704 analyzed; Edwards 1984). Moderate frequencies of carious teeth were found in the samples from Asia Beach (5.9 percent), Cardal (4.5 percent), Tablada de Lurín (5.9 percent), and Huaca Pucllana (7.2 percent). All fall within the range typical for populations with a mixed or horticultural subsistence base (Turner 1979).

Significantly higher rates of carious lesions in the Villa Salvador sample probably reflect a greater reliance on starchy carbohydrates than at the sites of earlier time periods. Stable isotope data also suggest a shift in dietary emphasis toward maize (Falk et al. 2004). The remains of both sexes from Villa Salvador exhibit a high frequency of caries (males, 13.5 percent; females, 26.9 percent), and a high percentage of adults had at least one carious lesion (males, 85 percent; females, 94 percent).

The rate of carious lesions in the Tablada de Lurín sample is lower than that for Villa Salvador and similar to those found in chronologically earlier collections. However, the individuals examined from Tablada de Lurín apparently lost an astounding 67 percent of their adult teeth antemortem. This high tooth loss may have resulted in an underestimation of the rate of carious lesions in the collection.

All of the dental samples, except for that from Tablada de Lurín, exhibit somewhat higher caries percentages for females than for males. This difference presumably reflects pregnancy- and lactation-related stress and/or dietary and behavioral differences between the sexes (Lukacs 1996). The inversion of caries percentages for males and females from Tablada de Lurín (5.8 percent for males and 4.4 percent for females) may be related to a higher frequency of tooth loss attributable to caries among females.

Morbidity and Mortality on the Central Peruvian Coast

Differential distribution of pathological lesions and physiological stress indicators among temporally distinct skeletal samples is potentially affected by three factors: by morbidity itself (Bennike et al. 2005); by morbidity-enhanced mortality in certain age groups (Wood et al. 1992; Wright and Chew 1998); and by changes in the specificity and sensitivity of disease indicators (Boldsen 2001). An increased likelihood of death among anemic children might lead to low frequencies of porotic hyperostosis among adults (Wright and Chew 1998). In a similar way, selectively high mortality of frail or undernourished children might lead to paradoxically higher adult stature in a population that is heterogenic for frailty (Saunders and Hoppa 1993; Kemkes-Grottenthaler 2005). Evolutionary changes in pathogenic microorganisms, as well as the introduction of new pathogens, can affect the frequency, topography, or morphology of bone lesions found in skeletal collections, without any change in the frequency of a particular illness. Therefore, in this analysis, particular attention was given to the distribution of pathological lesions among different age groups.

Indicators of Childhood Anemia

In precontact America, hyperostotic lesions of the cranial vault and orbital roof—porotic hyperostosis (PH) and cribra orbitalia (CO)—are commonly linked to acquired anemia (for example, Goodman, Martin, and Armelagos 1984; Steckel 2005; Blom et al. 2005), although other conditions can cause similar pathologies (Ortner et al. 1999; Ortner and Putschar 1985; El-Najjar 1979; Aufderheide and Rodriguez-Martin 1998). Alternatively, artificial cranial deformation has been proposed as a major contributing factor to the high

Table 7.3. Prevalence of Cribra Orbitalia (CO) and Porotic Hyperostosis (PH)

	CO freq. [n[a]]	PH freq. [n]
Paloma		
Adults	0.30 [69]	0.06 [69]
Subadults	0.18 [44]	0.14 [36]
Subadults adjusted	0.36	0.28
Asia and Río Seco		
Adults	0.57 [9]	0.43 [17]
Subadults	0.80 [5]	0.40 [5]
Cardal		
Adults	0.32 [15]	0.13 [21]
Male	0.38 [8]	0.11 [9]
Female	0.29 [7]	0.08 [12]
Subadults	0.67 [3]	0.22 [9]
Tablada de Lurín		
Adults	0.68 [22]	0.38 [26]
Males	0.50 [12]	0.45 [11]
Females	0.88 [9]	0.50 [10]
Subadults	0.00 [2]	0.00 [2]
Villa Salvador		
Adults	0.46 [60]	0.48 [61]
Males	0.61 [26]	0.58 [30]
Females	0.37 [32]	0.40 [30]
Subadults	0.86 [42]	0.59 [37]
Huaca Pucllana		
Adults	0.67 [18]	0.59 [17]
Huaca Huallamarca		
Adults	0.44 [9]	0.44 [9]
Subadults	1.00 [1]	0.00 [2]

Note: The category "Subadults" refers to skeletal remains with an estimated age at death of less than 20 years.

[a] n = the number of individuals that could be evaluated for presence of the respective indicator.

prehistoric frequency of porotic hyperostosis on the Peruvian coast (Aufderheide and Rodriguez-Martin 1998: 349). However, the low frequency of this pathology in the Cardal sample, in which approximately half of the crania were artificially modified, along with its high frequency in the Asia Beach sample, in which only one skull was intentionally deformed, argues to the contrary (Table 7.3).

Overall, Paloma adult crania display significantly lower frequencies of anemia indicators than the remainder of the Peruvian skeletal series examined, with only 30 percent of Paloma adult crania showing evidence of CO. The low frequency of anemia indicators in the Paloma skeletal series might be related to an apparent low parasitic load at the site. Paloma coprolites contain no evidence of intestinal worms. Karl Reinhard (pers. comm.) performed exten-

sive analyses on both coprolites and burial sediments from the site without finding any traces of parasite ova. Overall low human population density and the location of the site could have contributed to this phenomenon. Paloma is seven kilometers from the Río Chilca. Its residents probably depended on wells or moisture-collecting pits for fresh water (Quilter 1989), sources that would have been relatively clean and free of parasites.

The frequency of PH is very low in both the Paloma and Cardal samples, with only 6 percent of Paloma and 13 percent of Cardal adult crania displaying the signs of PH; these frequencies are significantly lower than those found for the same pathology in the other samples analyzed for the purposes of this study, which vary from 38 percent to 59 percent. The Asia Beach, Tablada de Lurín, Villa Salvador, Huaca Pucllana, and Huaca Huallamarca skeletal materials all display high frequencies of anemia indicators (Table 7.3). With the exception of the Asia Beach series, these collections come from contexts postdating the establishment of maize agriculture, a milestone documented to have precipitated an increase in the incidence of anemia elsewhere in the New World (for example, Buikstra and Cook 1980; Buikstra 1984).

The high frequency of PH in the Cotton Preceramic sample from the Asia Beach site can probably be ascribed to dependence on starchy plant foods (other than maize) of low dietary value. The high frequency of carious lesions among Asia dentitions suggests a high proportion of carbohydrates in the human diet there. Seeds of *guayaba,* a sweet fruit with a sticky texture, were common among the plant remains recovered at Asia (Engel 1963). Rich in carbohydrates, guayaba is nearly devoid of proteins and essential minerals. In addition, relatively high population density and the location of Asia on the bank of the Río Omas, close to the coast, would have increased the likelihood of contracting parasites, thus contributing to high rates of anemia, notwithstanding the absence of maize.

Relatively low frequencies of PH in the Initial period sample from the Cardal ceremonial center (PH, 13 percent; CO, 32 percent) are somewhat unexpected. Increased population densities during the Initial period might seem to predict poor hygiene and increased parasitic loads. However, greater population density alone appears not to have led to a marked increase in anemia or growth arrest episodes, and marine resources utilized at Cardal may have provided adequate dietary buffering.

As a rule, hyperostotic lesions are more frequent on subadult skeletal remains because they form during the first few years of life as a result of severe anemia, which increases the likelihood of early death (Steckel 2005). With one exception, the subadult remains examined in our study exhibit higher frequencies of CO than the adult samples (Table 7.3). The difference between adults and subadults is most pronounced in the Villa Salvador sample, in which mac-

Figure 7.2. Example of expansion of diploe on the Peruvian Central Coast.

roporosity of the orbital roof was recorded on 86 percent of subadult crania and on only 46 percent of adult crania. Expansion of the diploe in the cranial vaults of children from this sample was often profound (Figure 7.2). Similarly, in the Cotton Preceramic sample from the Asia Beach and Río Seco sites, 80 percent of subadult and only 57 percent of adult crania exhibited this pathology. Of the collections including a representative number of subadults, the frequency of CO on the crania of children is lower than that of adults only for Paloma.

Comparison of CO and PH frequencies among samples with different demographic profiles may be misleading because the frequencies of these pathologies vary tremendously between age groups (Figure 7.3). For instance, in the Paloma sample, close to 40 percent of subadults were infants, having estimated ages at death of less than one year (shown as a gray bar with dotted border in Figure 7.3). For this age group, recorded frequencies of CO and PH are zero, perhaps because the individuals died before hyperostosis was sufficiently advanced to be detectable by macroscopic examination.

Unlike at Paloma, infants under one year of age are not represented in the Villa Salvador sample. Furthermore, a steep decline in CO frequencies for age groups older than five years old is noticeable in both samples. Consequently,

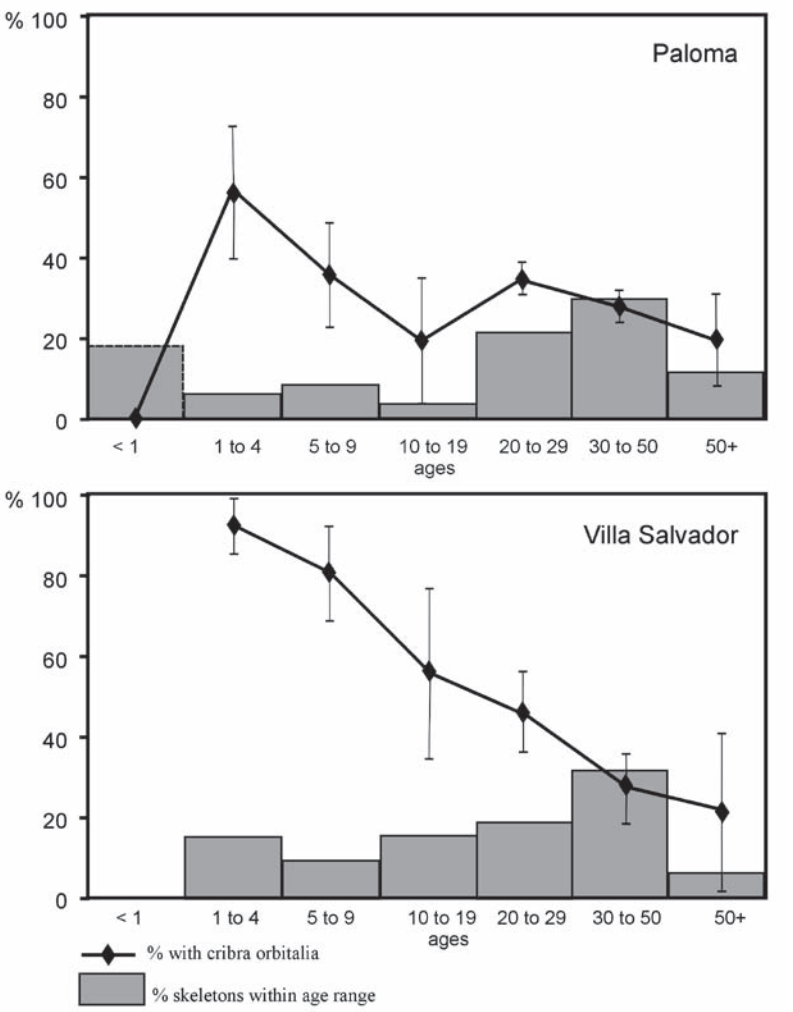

Figure 7.3. Frequency of cribra orbitalia from sites on the Peruvian Central Coast.

when pooled across age groups, the frequencies of CO and PH in subadult samples will vary in accordance with the proportion of infants in each age group. Removal of the skeletal remains of infants with an estimated age of less than one year from consideration in the Paloma sample increases the proportion of skulls with CO and PH to 36 percent and 28 percent, respectively.

The preponderance of PH and CO at Villa Salvador and the way in which the frequencies of those pathologies are distributed across the site's age groups suggest not only that anemia rates were higher in this chronologically later sample but also that anemia-related mortality among Villa Salvador subadults

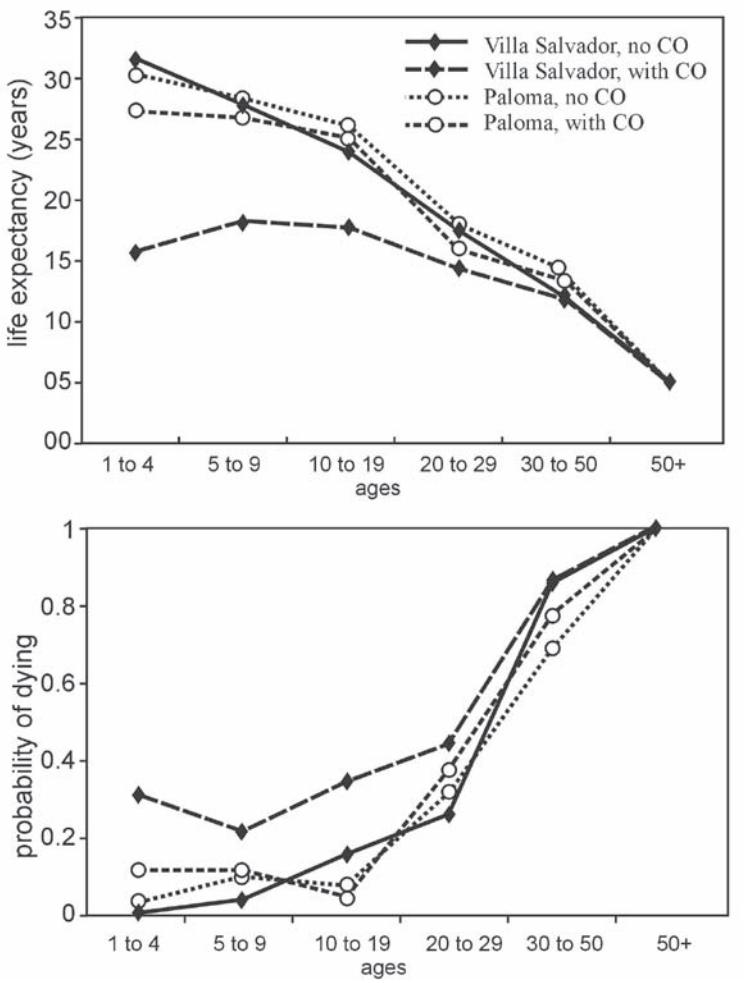

Figure 7.4. Life expectancy and probability of dying at sites on the Peruvian Central Coast.

was greater than at Paloma (Figure 7.4). For children with CO at Villa Salvador, the probability of dying at between one and four years of age was 31 percent, considerably higher than for children with no CO (0.7 percent). Affected individuals continued to experience increased mortality until the age of thirty. For the Paloma sample, the probability of death for children with CO was higher only between ages one and four (12 percent versus 0.4 percent). For older children, mortality was more or less random with respect to the presence or absence of anemia.

Systemic Infection

Most discussions of systemic infection among South American precontact populations are centered on the origin and spread of two pathogenic genera: *Mycobacterium,* the infectious agent responsible for tuberculosis, and *Treponema,* which is responsible for yaws, pinta, and venereal syphilis. On the basis of macroscopic, histological, and radiographic analyses of mummified and skeletonized human remains, numerous cases of pre-Columbian tuberculosis have been documented for populations from the Peruvian and Chilean coast (Allison et al. 1973, 1981; Buikstra and Williams 1991; Salo et al. 1994; Arriaza et al. 1995). *Mycobacterium* DNA has been isolated in several instances, making those diagnoses unequivocal (Arriaza et al. 1995; Salo et al. 1994). The earliest documented case of tuberculosis in Peru comes from the Chongos site, on the southern coast, which dates to circa AD 160 (Allison et al. 1981).

In our analysis, no clearly diagnostic cases of tuberculosis were found. One male skeleton from Villa Salvador had widespread periosteal bone formation on the long bones and thoracic vertebrae, as well as the visceral and lateral rib surfaces, which could suggest tuberculosis, but is more consistent with treponemal infection. Large resorptive lesions surrounded by oppositional bone (a pattern of lesions sometimes resulting from tuberculosis) were present on the anterior portions of the eighth and ninth thoracic vertebrae of a male skeleton from Huaca Huallamarca.

Periosteal lesions were most common on tibias and distal femurs, a pattern also suggestive of treponemal infection (Figure 7.5). Both the Paloma and Cardal collections exhibit relatively high frequencies of bilateral periosteal lesions among subadults, suggesting nonvenereal, probably yawslike, treponematosis (Table 7.4). For Paloma subadults, periosteal lesions were more common in children five to nine years old than in younger children (Figure 7.6).

A shift in the epidemiology of treponematosis could have occurred sometime between the Initial period and the Early Intermediate period. At Villa Salvador, systemic infection became common in adults, particularly males, whereas subadults appear to have been practically unaffected (Table 7.4). Among adults, the frequency of systemic infection declined slightly in individuals aged 50+, while the degree of both severity and healing increased. Adult mean ages at death for affected individuals (males, 34.0; females, 36.7) are similar to those of unaffected individuals (males, 35.3; females, 35.5), suggesting that chronic treponematosis did not increase the likelihood of death during adulthood.

Generalized periosteal lesions were practically absent from the Huaca Pucllana and Huaca Huallamarca skeletal collections. Analysis of the relatively

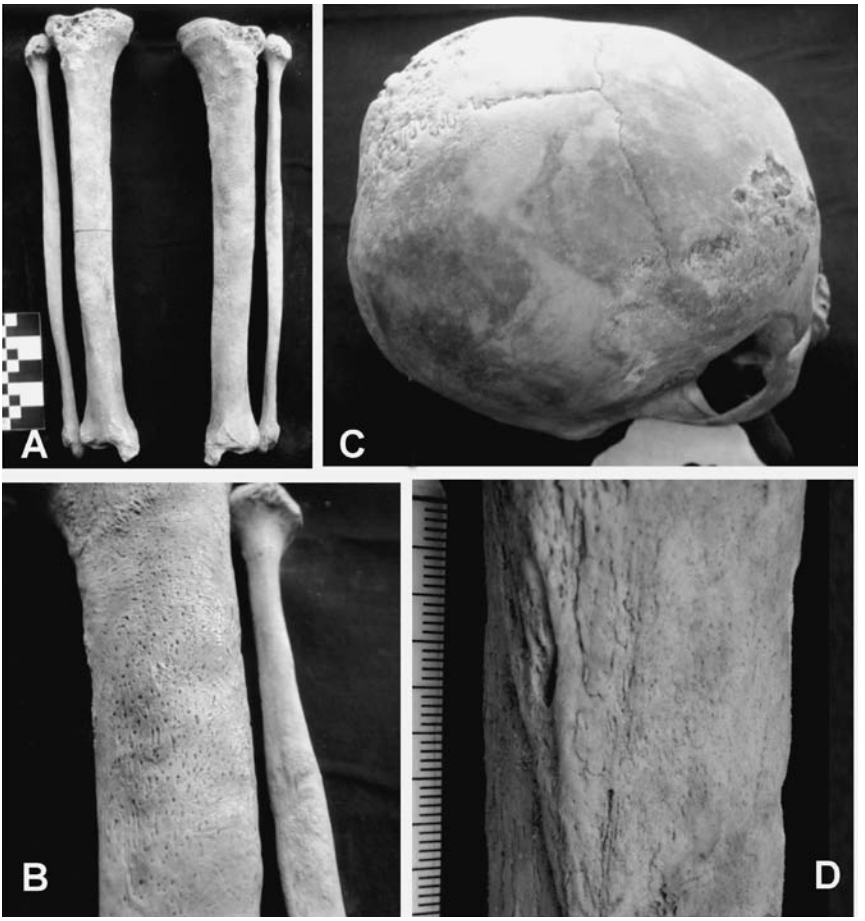

Figure 7.5. Examples of treponemal infection on the Peruvian Central Coast.

small Huaca Pucllana sample, which is heavily weighted toward young females, may suffer from the effects of sampling error. However, the relatively large sample from Huaca Huallamarca displayed almost no generalized periostosis on the diaphyses of long bones, suggesting either that treponematosis had declined significantly by the later part of the Early Intermediate period or that its pathogenesis had changed.

The distribution of periosteal and hyperostotic lesions among the age groups for Paloma subadults suggests that the likelihood of anemia- and systemic infection–related death varied with age (compare Figure 7.3 and Figure 7.6). Hyperostotic lesions were found predominantly on the remains of infants who died between ages one and four, while periosteal lesions were more common in the older age groups. Only one subadult skeleton displayed both

Table 7.4. Frequency of Individuals with Skeletal Lesions Suggestive of Systemic Infection

Site	Individuals with Generalized Periosteal Lesions			
	Total Adults freq. [n[b]]	Males freq. [n]	Females freq. [n]	Subadults[a] freq [n]
Paloma	0.22 [87]	0.28 [40]	0.18 [40]	0.11 [57]
Chilca One	0.25 [4]	0.33 [3]	0.00 [1]	—
Asia Beach	0.30 [10]	0.20 [5]	0.40 [5]	0.00 [2]
Río Seco	0.50 [2]	0.50 [2]	—	0.00 [2]
Cardal	0.50 [16]	0.28 [7]	0.62 [8]	0.75 [12]
Tablada de Lurín	0.51 [35]	—	—	0.00 [4]
Villa Salvador	0.23 [82]	0.53 [36]	0.11 [46]	0.00 [38]
Huaca Pucllana	0.04 [24]	0.50 [2]	0.00 [22]	—
Huaca Huallamarca	0.03 [34]	0.05 [20]	0.00 [14]	0.00 [18]

[a] Estimated age at death of less than 20 years.

[b] n = the number of individuals that could be evaluated for presence of the respective indicator.

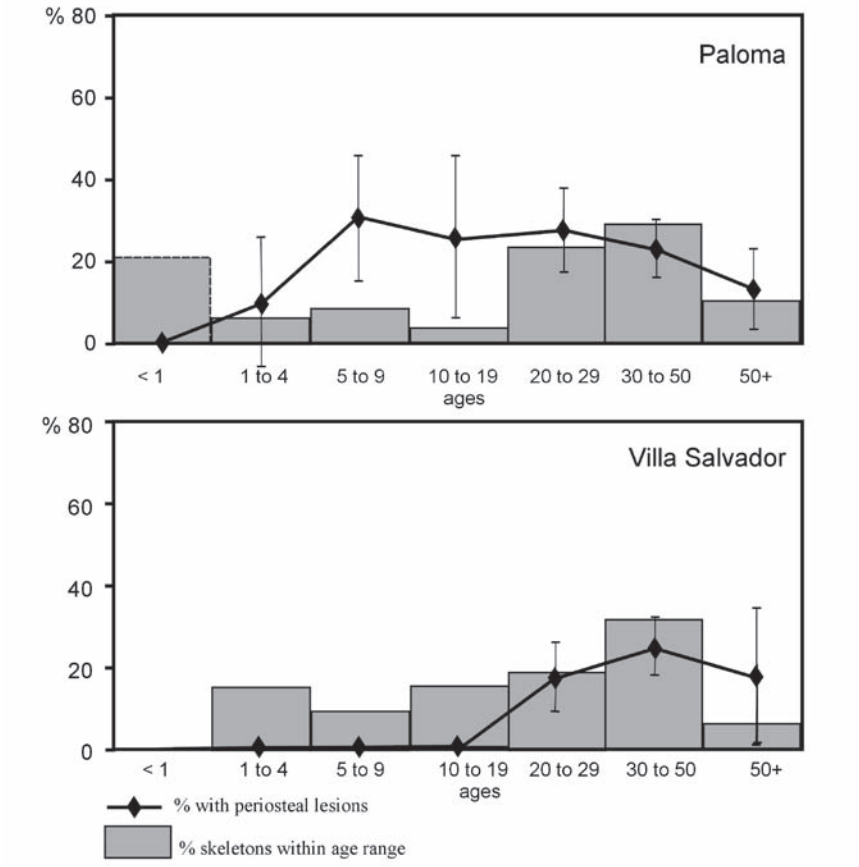

Figure 7.6. Frequency of periosteal lesions at sites on the Peruvian Central Coast.

types of lesions. Slightly more children with CO seem to have survived into adulthood than died before reaching sexual maturity, tentatively supporting a protective role for anemia in increasing resistance to infection (P. Stuart-Macadam 1992).

Achieved Adult Stature

Changes through time in adult stature among the sampled populations are remarkable. The average adult stature of the Paloma fishers was significantly higher than that for subsequent populations from the central Peruvian coast (Table 7.5). Pairwise comparisons of Paloma long bone lengths with those from other representative samples result in high *t*-statistic values with a probability below 0.001.

Table 7.5. Long Bone Measurements and Stature Estimates

	Measurement				
Site	Humerus Max Length (mm)[*n*]	Humerus Head (mm)[*n*]	Femur Max Length (mm)[*n*]	Femur Head (mm)[*n*]	Stature[a] (cm)
Paloma					
Males	309.8±10.4[17]	43.7±2.1[33]	436.2±18.9[18]	45.3±2.1[24]	165.1
Females	284.8±10.8[24]	37.4±7.0[29]	395.8±18.3[16]	39.9±2.1[29]	155.2
Río Seco					
Males	299.5±4.9[2]	43.5±0.7[2]	415.5±17.7[2]	43.5±2.12[2]	160.1
Females	—	—	—	—	—
Asia Beach					
Males	287.0±9.5[9]	42.4±1.7[9]	415.4±12.5[12]	42.6±2.0[12]	160.0
Females	264.2±31.8[7]	37.8±2.8[6]	389.5±16.2[6]	38.9±2.1[6]	153.7
Cardal					
Males	262.7±18.8[5]	39.5±2.9[3]	376.8±23.4[5]	—	150.6
Females	236.5±16.2[7]	34.5±1.5[6]	344.2±20.2[7]	—	142.7
Villa Salvador					
Males	302.1±14.9[27]	42.2±2.1[29]	412.2±20.6[25]	43.8±2.1[28]	159.2
Females	275.3±13.4[29]	36.6±2.6[28]	385.2±16.4[31]	39.7±2.1[36]	152.7
Tablada de Lurín					
Males	306.0±8.3[6]	—	414.0±10.8[9]	—	159.7
Females	296.2±4.2[2]	—	389.5±7.8[2]	—	153.7
Huaca Pucllana					
Males	311.5±57.3[2]	43.7±3.8[3]	396.0±5.7[2]	47.0±9.9[2]	155.3
Females	273.3±19.7[10]	35.8±1.6[7]	368.0±16.8[15]	37.9±2.6[7]	148.5
Huaca Huallamarca					
Males	300.0±8.7[12]	43.2±2.4[12]	412.1±13.4[20]	45.0±2.4[21]	159.2
Females	279.8±13.2[12]	37.6±1.2[11]	385.7±14.2[14]	41.1±2.3[15]	152.8

Note: Max Length = calculated maximum length of available bones; Head = circumference; *n* = number of observable bone elements.

[a] Stature estimates are based on Mexican male formula for the femur from Trotter 1970.

Table 7.6. Femur Length versus Age at Death in Children Six Years of Age and Younger

Dental Age (months)	Paloma (mm)[*n*]	Asia Beach (mm)[*n*]	Villa Salvador (mm)[*n*]	Huaca Huallamarca (mm)[*n*]
0–11	78.0 [4]	—	64.0 [1]	62.0 [4]
12–23	130.0 [3]	128.0 [1]	115.0 [3]	118.0 [1]
24–35	150.0 [2]	—	140.0 [3]	—
36–47	179.0 [3]	—	173.3 [6]	177.0 [1]
48–71	247.2 [5]	—	210.0 [4]	213.0 [1]

Note: *n* = number of observable elements.

Among the adult skeletal samples examined, two stand out as comprising remarkably short individuals. These include the remains from the ceremonial centers at Cardal (Initial period) and Huaca Pucllana (Early Intermediate period). Some individuals buried in ceremonial centers might not have been representative members of their local communities. Some burials at these centers might have been those of captives or low-status individuals who did not get adequate alimentation during childhood. At Huaca Pucllana, young females were overrepresented. Two from multiple interments had perimortem stab wounds in the arches of their cervical vertebrae; two skeletons from the same site each lacked a cranium. It seems likely that all these burials were ceremonial. Immigration from high altitudes, population replacement, or increased physiological stress in the context of rapid population growth are other factors that could have contributed to shorter adult stature at Cardal and Huaca Pucllana.

A higher mortality rate for short, frail children (as opposed to differing growth trajectories for subadults) is another possible explanation for the differences in adult stature among the samples. Only the Paloma and Villa Salvador collections have a sufficient number of subadult postcrania to permit a meaningful comparison of long bone length between the corresponding age cohorts (Table 7.6). In every age group, Paloma children were taller than children from Villa Salvador. When the effect of age was adjusted for by regression and the residuals of femur lengths were compared between the Paloma and Villa Salvador samples, Paloma children were found to be significantly taller than those from Villa Salvador (t=2.45, 20 df, p<0.02). Consequently, the observed difference between adult statures in the Villa Salvador and Paloma samples cannot be explained by higher frailty-related mortality in either group. Taller Paloma children simply grew into taller adults.

Growth Arrest Episodes

Growth arrest lines on teeth are interpreted as resulting primarily, but not exclusively, from periods of systemic physiological stress (Goodman, Armelagos, and Rose 1984; Goodman and Rose 1991; Fitzgerald and Rose 2000). A negative correlation between achieved adult stature and the number of growth arrest episodes is expected. However, no direct correspondence was observed between average adult stature and the frequency of growth arrest lines on permanent anterior teeth (Table 7.7). Although the lowest frequency of hypoplasias was found in the Paloma sample (6 percent), which also had the greatest average adult stature, it was closely followed in that respect by the Cardal sample (16 percent), which had the shortest average adult stature. The highest frequency of hypoplastic teeth was observed for the Huaca Pucllana females (86 percent of anterior teeth), a sample with the second-shortest average adult stature for our total data set.

With the exception of the Cardal sample, male dentitions showed higher frequencies of hypoplastic teeth than female dentitions did, suggesting that males either experienced greater early childhood stress than females or had higher recovery rates. However, these differences are slight.

The age at which a growth arrest episode occurred can be evaluated from linear enamel hypoplasias and measured on the permanent anterior dentition by the half year from birth to 6.5 years of age (Goodman, Lallo et al. 1984; Massler et al. 1941; Moorrees et al. 1963a). The distribution of hypoplasias by age was similar in all samples, with the majority of growth arrest episodes occurring between 2.5 and 4.4 years of age and the peak of hypoplasia formation at between 3 and 4 years of age. This peak is best defined for the Cardal and Asia Beach dental sets, in which 43 percent and 40 percent of the respective growth arrest episodes occurred between ages three and four. For the Paloma sample, this peak is less clearly defined and occurred somewhat later. Only 15 percent of the hypoplasias recorded for Paloma teeth occurred between ages 3 and 3.4, 20 percent between 3.5 and 3.9, and another 15 percent between the ages of 4 and 4.4 years. Similarly, in the Cardal sample, 21 percent of growth arrest episodes occurred between the ages of 3.5 and 3.9; in other dental samples examined, this frequency did not exceed 16 percent. The delayed age of hypoplasia formation among individuals from the Paloma and Cardal samples might be related to a delayed introduction of solid foods or to a different dynamic for parasite contraction among those populations.

The patterns of hypoplasia formation determined for the Villa Salvador and Tablada de Lurín samples are very similar. Both exhibit a relatively even distribution of hypoplasias by age, especially between the ages of 2 and 4: 15 percent of growth arrest lines formed between ages 2.5 and 2.9, 18–19 percent formed

Table 7.7. Frequencies of Enamel Hypoplasias by Sex and Age of Formation

	% Teeth with Enamel Hypoplasia[a]				% Hypoplasia Formed by Age Group					
Site	*n*[b]	Adults[c]	Males	Females	2–2.4	2.5–2.9	3–3.4	3.5–3.9	4–4.4	4.5–4.9
Paloma	260	6	—	—	7	10	15	20	15	8
Asia Beach	143	36	33	65	8	12	24	16	8	12
Cardal	100	16	8	37	6	12	22	21	12	8
Tablada de Lurín	119	47	57	42	10	15	18	14	15	5
Villa Salvador	331	42	44	66	7	15	19	16	12	10
Huaca Pucllana	123	86	—	86	—	—	—	—	—	—

[a] Frequency of enamel hypoplasia is estimated based on anterior teeth only.
[b] *n* = number of permanent anterior teeth analyzed.
[c] including males, females, and sex-indeterminate individuals.

between ages 3 and 3.4, and 14–16 percent formed between ages 3.5 and 3.9. This correspondence in the distribution of evidence for growth arrest episodes preserved on anterior teeth suggests a similar incidence of acute illness among children and/or starvation periods at both sites, notwithstanding the location of the Tablada de Lurín Necropolis somewhat upstream from Villa Salvador.

Discussion and Conclusions

Based on the analysis of human skeletal remains presented here, several prehistoric trends in community health on the central Peruvian coast can be tentatively outlined. The Middle Preceramic sample (Paloma) exhibits the lowest rates of all indicators of physiological stress, the lowest rate of caries, and the tallest adult stature for both sexes. A significant deterioration of health during the subsequent periods is suggested by the majority of skeletal indicators. The only exception to this pattern is the frequency of systemic infection, which appears to have already been relatively high at Paloma.

Oral health, as reflected by the incidence of caries, declined significantly during the Cotton Preceramic and remained about equally depressed through the Initial period. This early increase in caries formation was probably caused by a growing reliance on starchy cultivated plant foods, as well as increased population density. The later transition to maize agriculture led to a further increase in the rates of caries formation and antemortem tooth loss.

The Cotton Preceramic and Initial periods also seem to have witnessed an overall increase in the frequency of physiological stress indicators, including cribra orbitalia, porotic hyperostosis, and the formation of enamel hypoplasias, although the Cardal skeletal sample (Initial period) resembles Paloma in its relatively low frequencies of porotic hyperostosis and enamel hypoplasias. Chronic anemia became a strong contributing factor to subadult mortality

during the Cotton Preceramic and in subsequent time periods. However, there does not seem to have been a clear trend toward any further increase in subadult physiological stress with the adoption of maize agriculture. The Early Intermediate period Villa Salvador and Tablada de Lurín skeletal collections exhibit frequencies of anemia indicators and evidence of growth arrest episodes similar to those of the Cotton Preceramic Asia Beach sample.

Achieved adult stature for individuals from Paloma was the highest observed. This growth was likely supported by an adequate protein intake and low parasitic loads. For skeletal samples from the subsequent time periods, stature shows large-scale oscillations that might be better explained by population relocation than by changes in either health or diet.

Two shifts in the epidemiology of treponematosis can be tentatively proposed based on the study reported here. Systemic infection commonly affected subadults at both Paloma and Cardal but was virtually absent among children from later populations. Therefore, a change in the mode of transmission of treponematosis from contact to venereal during the Early Horizon or the first half of the Early Intermediate period can be proposed. A second shift probably took place during the Middle Horizon, as the frequency of lesions suggestive of infectious disease on human remains from that time period is relatively low.

We conclude that increased population density, accompanied by a decline in the effectiveness of communal sanitary practices, led to increased physiological stress and parasitic loads among human populations on the Peruvian coast. The eventual transition to intensive maize agriculture resulted in a significant deterioration of oral health, but its effect on other stress and health indicators was not as dramatic.

Acknowledgments

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8

The Adoption of Agriculture among Northern Chile Populations in the Azapa Valley, 9000–1000 BP

MARTA P. ALFONSO, VIVIEN G. STANDEN, AND M. VICTORIA CASTRO

Various studies have shown the adoption of agriculture to have had a negative impact on the health status of past populations (Cohen and Armelagos 1984; Cohen 1989). Others, in contrast, demonstrate that this process has a positive effect on health, mortality, fertility, and life expectancy (Buikstra et al. 1986; Benfer 1990).

This chapter analyzes the effects that the adoption of agriculture had on coastal and inland groups of the Azapa Valley of northern Chile. The skeletal samples correspond to hunter-gatherers, groups of mixed economy, and agriculturalists. The quality of these strategies is assessed through dental health and enamel hypoplasia; life expectancy tables are used to evaluate their relative success.

Background

ENVIRONMENT

The Azapa Valley, part of the Atacama Desert (Figure 8.1), is marked by extreme temperatures, daily thermal oscillation, scarce vegetation, and high soil salinity (Sepúlveda 1962; Nuño and Barros 1984; Toledo and Zapater 1991; Corporación Tiempo 2000, 1993). The coast has abundant and varied marine resources, and the shore is inhabited by terrestrial mammals, birds, and insects (Gemines 1980; Quintanilla 1983).

Inland, the San Jose River waters the Azapa Valley seasonally, increasing the humidity (Gemines 1982). The salinity of the soil, however, reduces the quality and variety of cultigens (Keller 1946; Toledo and Zapater 1991).

REGIONAL PREHISTORY OVERVIEW

The Archaic period (9000–3700 BP) is characterized by coastal semisedentary hunter-gatherer-fisher groups, the Chinchorro, whose mortuary practices were highly complex (Schiappacasse and Niemeyer 1984; Focacci and

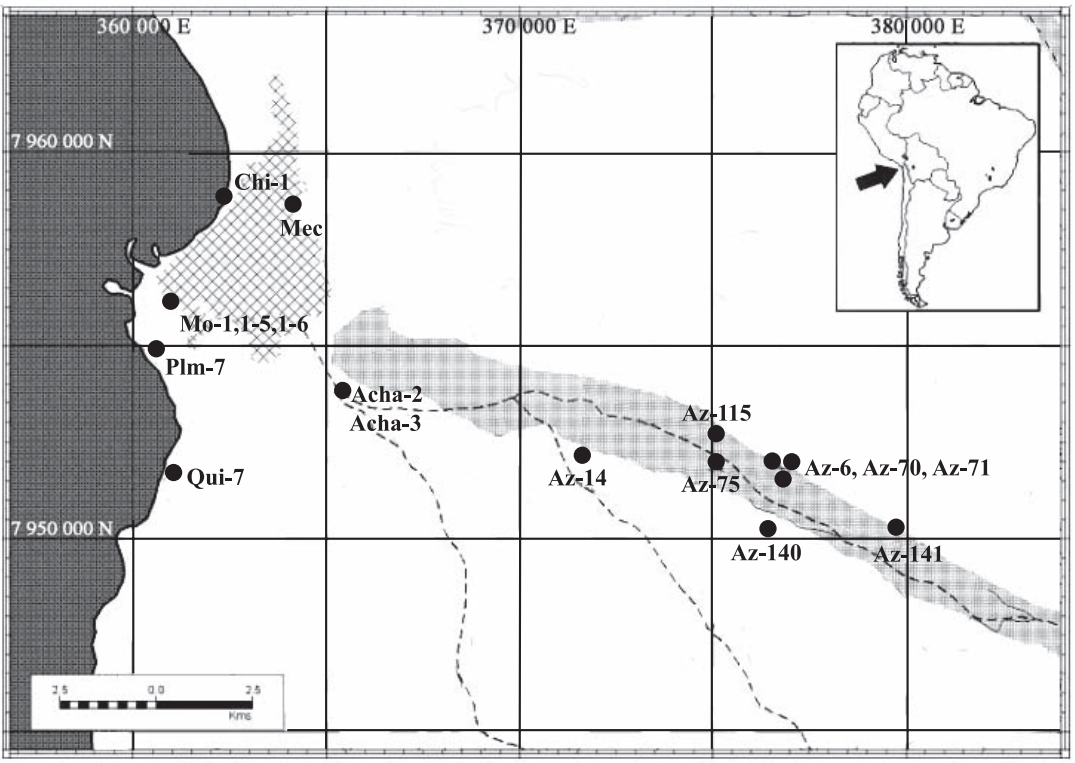

Figure 8.1. Locations of northern Chilean sites.

Chacón 1989; Nuñez 1967, 1989; Santoro 1989; Arriaza et al. 1993; Muñoz and Chacama 1993; Guillén 1992; Arriaza 1994, 1995; Standen 1991, 1997, 2004). Parasites, commonly found in seafood, resulted in high frequencies of cribra orbitalia and porotic hyperostosis among these groups (Hart et al. 1998).

At the beginning of the Formative period (3700–1500 BP), segments of the coastal populations moved inland, settling in villages, although coastal occupations continued (Focacci 1974; Santoro 1980a, 1980b, 1982; Muñoz 1989; Muñoz et al. 1993). Cultivation and the adoption of pottery mark the period (Santoro 1980a, 1980b; Muñoz 1982, 1983; Sutter 1997, 2000, 2005; Sutter and Mertz 2004). The first inland occupations display a mixed economy, with the residents cultivating quinoa, beans, yucca, chili peppers, beans, squash, manioc, maize, and sweet potatoes among others (Santoro 1980a, 1980b, 1982). Coprolites indicate a fairly homogenous diet primarily composed of vegetables (Muñoz 1987). Interdependent specialists, herders, farmers, and coastal hunter-fishers-foragers, as well as increased social complexity emerged during this period (Nuñez 1989; Nuñez and Dillehay 1995).

During the Middle Horizon (1600–1000 BP) (Focacci 1985, 1989; Rivera 1985, 1994; Muñoz 1987), inland populations practiced agriculture and were characterized by complex social organization and elites. No coastal populations have been identified. Agricultural practices provided the main subsistence. The diet included maize, squash, beans, and sweet potatoes, camelids, guinea pigs, and shellfish (Berenguer and Dauelsberg 1989; Dauelsberg 1992–93).

Materials and Methods

The sample studied is composed of 526 individuals from twenty osteological collections (Table 8.1). The number of observations for each dental pathology varies with preservation. Six dental pathologies were analyzed in this study: (1) antemortem tooth loss, or AMTL (Lukacs 1989); (2) dental wear, including degree (Smith 1984) and shape (Molnar 1971); (3) alveolar resorption (in mm; Clarke et al. 1986); (4) abscesses, including presence/absence and size; (5) caries, including presence/absence, number, degree (Lukacs 1989), and location; and (6) enamel hypoplasia, or EH, including presence/absence, percentage of teeth with multiple defects (PMHD), and age at the time of formation (El-Najjar et al. 1978; Lukacs 1989; Goodman and Rose 1990). Formative period coastal and inland groups are analyzed separately. Individuals of the same age-sex category are compared between periods. Sex categories in the same age range are compared within each period. Only inland groups of the Formative period are compared with the groups of the Middle Horizon. The information was organized by seven age categories: 0–2, 3–12, 13–18, 19–24, 25–29, 30–40, and >40 years old. Sample sizes are reported in the tables. Standard statistical tests were applied (Steel and Torrie 1988; Milton 1994).

Results

DENTAL PATHOLOGIES

Archaic period

Males aged 13–18 are the first to present antemortem tooth loss (AMTL; 3.8 percent). Over the age of 25, AMTL is present in all age-sex categories, and its percentage increases with age (Table 8.2).

The percentage of teeth with alveolar resorption in subadult individuals increases with age, but the degree of alveolar resorption is pathological only after the age of 19 ($\mu \geq 2$ millimeters; Table 8.2).

Abscesses appear in individuals aged 19 years and over. The percentage of teeth affected increases with age. Abscesses developed earlier in males (age

Table 8.1. Number of Individuals and Teeth Analyzed

	Number of Individuals				Number of Teeth			
Age	Female	Male	Undet.	Total	Female	Male	Undet.	Total
Archaic								
0–2			12	12			120	120
3–12			17	17			227	227
13–18	5	2		7	113	26		139
19–24	1	3		4	29	42		71
25–29	7	5		12	132	93		225
30–40	18	24		42	334	333		667
>40	4	11		15	47	205		252
Total	35	45	29	109	655	699	347	1,701
Coastal Formative								
0–2				0				0
3–12			8	8			65	65
13–18	3			3	21			21
19–24	2	2		4	24	56		80
25–29	5	3		8	81	39		120
30–40	19	21		40	369	280		649
>40	8	7		15	113	108		221
Total	37	33	8	78	608	483	65	1,156
Inland Formative								
0–2			16	16			178	178
3–12			24	24			275	275
13–18	7	1		8	95	27		122
19–24	6	8		14	95	182		277
25–29	5	4		9	112	70		182
30–40	13	21		34	239	360		599
>40	7	9		16	173	169		342
Total	38	43	40	121	714	808	453	1,975
Middle Horizon								
0–2			25	25			249	249
3–12			47	47			731	731
13–18	6	13		19	146	234		380
19–24	12	12		24	303	293		596
25–29	6	8		14	132	158		290
30–40	28	16		44	480	247		727
>40	31	14		45	693	337		1,030
Total	83	63	72	218	1,754	1,269	980	4,003

Note: Age in years at the time of death. Undet. = undetermined sex.

19–24, 2.4 percent) than in females (age 25–29, 3.4 percent). Most abscesses are on buccal surfaces (Table 8.2).

Among both subadults (0–18 years old) and adults (>18 years old), the percentage and degree of dental wear increases with age, so that by age 30 most teeth are worn (Table 8.3). Within most age-sex segments, the most common shape of dental wear is the plane.

No caries were identified among subadults (0–18 years old). All caries among females aged 19–24 are from one individual and thus, do not reflect

Table 8.2. Archaic Period Antemortem Tooth Loss, Alveolar Resorption, and Abscesses

	AMTL	**Alv. Res.**		**Abscesses**			
Age/Sex	%	%	μ	%	μ	B	L
0–2	0	58.6	1.7	0	0	0	0
3–12	0	75.9	1.7	0	0	0	0
13–18 Female	0	84.8	1.7	0	0	0	0
13–18 Male	3.8	100.0	1.9	0	0	0	0
19–24 Female	0	93.1	2.0	0	0	0	0
19–24 Male	2.4	100.0	2.5	2.4	7.0	100.0	0
25–29 Female	4.6	99.2	2.2	3.4	3.8	100.0	0
25–29 Male	5.4	98.9	2.7	2.3	3.5	100.0	0
30–40 Female	11.2	100.0	3.3	5.2	4.1	84.2	15.8
30–40 Male	14.4	98.5	3.6	5.6	5.1	94.7	5.3
>40 Female	27.7	100.0	3.9	19.1	7.7	50.0	50.0
>40 Male	6.8	100.0	3.8	8.1	6.1	93.3	6.7

Note: Age in years at the time of death. AMTL = antemortem tooth loss; Alv. Res. = alveolar resorption; % = percentage; μ = average; B = buccal; L = lingual.

Table 8.3. Archaic Period Dental Wear

Age/Sex	%	μ	P	PC	C	R
0–2	14.3	2.0	100.0	0	0	0
3–12	67.4	2.5	56.8	43.2	0	0
13–18 Female	78.3	3.3	66.7	33.3	0	0
13–18 Male	100.0	5.8	42.5	44.2	3.8	9.3
19–24 Female	89.7	3.3	54.2	41.7	4.2	0
19–24 Male	95.1	3.3	100.0	0	0	0
25–29 Female	99.7	4.5	52.5	36.7	8.3	2.5
25–29 Male	97.6	4.9	51.3	38.5	5.1	5.1
30–40 Female	99.7	5.2	58.8	32.5	0	8.8
30–40 Male	100.0	4.8	44.6	46.4	6.5	1.8
>40 Female	100.0	6.4	20.0	80.0	0	0
>40 Male	100.0	5.9	28.4	55.3	10.5	5.8

Note: Age in years at the time of death. % = percentage; μ = average; P = plane; PC = partially concave; C = concave; R = round.

the dental health status of the general group. Most caries among all age-sex categories are occlusal and minimal (30 percent of crown affected). As is characteristic of hunter-gatherer adaptation, the overall frequency of caries is low (Table 8.4).

Formative period

In general, AMTL is more common among inland than coastal groups. Females tend to present a higher percentage of AMTL than do males in both

Table 8.4. Archaic Period Caries

Age/Sex	%	μ	NC	O	C	CC	CR	R
0–2	0	0	0	0	0	0	0	0
3–12	0	0	0	0	0	0	0	0
13–18 Female	0	0	0	0	0	0	0	0
13–18 Male	0	0	0	0	0	0	0	0
19–24 Female	10.3	1	3	100.0	0	0	0	0
19–24 Male	0	0	0	0	0	0	0	0
25–29 Female	0	0	0	0	0	0	0	0
25–29 Male	0	0	0	0	0	0	0	0
30–40 Female	2.4	1	7	100.0	0	0	0	0
30–40 Male	0.7	1	2	50.0	0	50.0	0	0
>40 Female	5.0	1	1	100.0	0	0	0	0
>40 Male	0.5	1	1	100.0	0	0	0	0

Note: Age in years at the time of death. % = percentage; μ = average; NC = number of caries; O = occlusal; C = coronal; CC = cervical-coronal; CR = cervical-root; R = root.

Table 8.5. Formative Period Antemortem Tooth Loss and Alveolar Resorption

	AMTL		**Alveolar Resorption**			
	Coastal	Inland	Coastal		Inland	
Age/Sex	%	%	%	μ	%	μ
0–2		0			80.1	1.6
3–12	0	1.1	83.9	1.8	85.7	1.8
13–18 Female	0	0	88.2	1.8	83.2	1.8
13–18 Male	0	0			59.3	1.3
19–24 Female	4.2	4.2	95.6	1.9	94.5	2.7
19–24 Male	0	6.0	94.6	2.3	97.0	2.5
25–29 Female	4.9	13.4	100.0	2.6	100.0	2.7
25–29 Male	0	5.7	94.7	2.7	96.6	5.6
30–40 Female	8.7	16.7	99.4	3.2	98.9	3.9
30–40 Male	6.1	1.4	100.0	3.3	98.4	3.3
>40 Female	16.8	45.7	98.8	3.5	100.0	5.5
>40 Male	34.3	47.3	100.0	4.6	100.0	3.6

Note: Age in years at time of death. % = percentage; μ = average; AMTL = antemortem tooth loss.

coastal and inland groups. The frequency of AMTL increases from the Archaic to the Formative period, especially among inland individuals (Table 8.5).

Alveolar resorption appears at an early age and affects a high percentage of teeth. Until the age of 19 years, the resorption is below 2 millimeters (and therefore normal), but it becomes more severe and pathological with age (Table 8.5). Over all, the average degree of alveolar resorption in coastal and inland groups is similar to that of the Archaic period. Comparatively, however, inland Formative groups show a higher degree—although not significantly so—of alveolar resorption when compared to Archaic and coastal Formative groups.

Table 8.6. Formative Period Abscesses

	Coastal				Inland			
Age/Sex	%	μ	B	L	%	μ	B	L
0–2					0	0	0	0
3–12	0	0	0	0	0.4	4.1	100.0	0
13–18 Female	0	0	0	0	2.1	6.3	66.7	33.3
13–18 Male					0	0	0	0
19–24 Female	0	0	0	0	0	0	0	0
19–24 Male	0	0	0	0	1.2	2.3	100.0	0
25–29 Female	3.8	6.7	66.7	33.3	1.0	6.0	100.0	0
25–29 Male	0	0	0	0	1.5	2.0	100.0	0
30–40 Female	9.6	4.8	87.5	12.5	5.0	6.7	90.9	9.1
30–40 Male	5.3	5.5	84.6	15.4	2.9	3.8	91.7	8.3
>40 Female	3.8	2.3	100.0	0	3.2	1.7	100.0	0
>40 Male	15.0	5.4	91.7	8.3	8.9	4.9	100.0	0

Note: Age in years at the time of death. % = percentage; μ = average; B = buccal; L = lingual.

Coastal groups from the Archaic and Formative periods have a similar pattern of alveolar resorption.

Low percentages of dental abscesses were found in Formative inland and coastal groups. In comparison to the Archaic, Formative inland groups show a slight decrease in abscesses that is significant only among older females (Tables 8.2 and 8.6; Archaic/Formative: females >40, z=1.96, p=.03). This difference is probably a result of both less severe dental wear and the superficial nature of caries.

No significant differences in the average size or in the location (predominantly buccal) of abscesses were found between Formative inland and coastal groups or between Formative and Archaic groups (Table 8.6).

The percentage of teeth with dental wear and the average degree of dental wear in the Formative period increases with age. In most age-sex segments, the most common shape of wear is the partially concave (Table 8.7). The average degree of dental wear is similar in Formative coastal and inland individuals. No differences were identified in the percentage of worn teeth between Archaic and Formative groups. The average degree of wear, however, is lower among Formative groups than among Archaic groups. Additionally, inland and coastal Formative individuals show a higher percentage of teeth worn in the concave shape, while plane-shape wear occurs at half the frequency of the Archaic period (Tables 8.3 and 8.7) and is significantly more common among coastal than inland Formative adults (Table 8.7; females 19–24, z=7.39, p=.00; males 19–24, z=6.21, p=.00; males 25–29, z=2.46, p=.01; females 30–40, z=1.87, p=.03; females >40, z=2.99, p=.00; males >40, z=5.96, p=.00).

Table 8.7. Formative Period Dental Wear

	Coastal						Inland					
Age/Sex	%	μ	P	PC	C	R	%	μ	P	PC	C	R
0–2							34.8	2.2	77.4	21.0	1.6	0
3–12	64.9	3.2	5.4	94.6	0	0	64.4	2.9	23.7	74.6	1.7	0
13–18 Female	88.2	2.7	6.7	80.0	13.3	0	74.7	2.9	23.9	76.1	0	0
13–18 Male							50.0	2.2	30.8	69.2	0	0
19–24 Female	100.0	3.4	56.5	43.5	0	0	94.4	4.3	13.1	85.7	1.2	0
19–24 Male	89.1	3.5	46.9	51.0	0	0	94.4	3.1	20.3	75.2	4.6	0
25–29 Female	91.5	3.1	18.5	77.8	3.7	0	98.9	4.3	22.9	72.9	4.2	0
25–29 Male	89.5	2.9	20.6	79.4	0	0	100.0	4.1	12.3	86.2	1.5	0
30–40 Female	99.5	4.5	25.9	68.6	4.3	1.1	97.3	4.4	15.3	77.0	3.3	4.4
30–40 Male	100.0	4.2	22.5	72.1	3.9	1.5	98.0	4.5	17.6	69.7	10.5	2.0
>40 Female	100.0	5.6	16.7	65.5	7.1	10.7	100.0	5.9	7.7	64.8	19.8	7.7
>40 Male	100.0	5.5	22.7	68.2	1.5	3.0	98.8	5.2	3.6	78.3	12.0	6.2

Note: Age is in years. % = percentage; μ = average; P = plane; PC = partially concave; C = concave; R = round.

Caries are present in both coastal and inland groups but appear at an earlier age among the latter (Tables 8.8 and 8.9). In fact, inland individuals show a significantly higher percentage of teeth with caries in comparison to coastal ones (subadults 3–12, z=-3.74, p=.00; females 19–24, z=-3.03, p=.00; males 19–24, z=-4.28, p=.00; males 25–29, z=-1.77, p=.04; females 30–40, z=-7.79, p=.00; males 30–40, z=-8.49, p=.00; males >40, z=3.99, p=.00). Caries frequencies increase along with age in inland but not coastal groups; among the latter, caries frequencies are low for all age-sex segments (<5 percent; Tables 8.8 and 8.9).

Table 8.8. Formative Period Caries among Coastal Groups

			Incidence					
Age/Sex	%	μ	NC	O	C	CC	CR	R
0–2								
3–12	0	0	0	0	0	0	0	0
13–18 Female	5.9	1	1	100.0	0	0	0	0
13–18 Male								
19–24 Female	0	0	0	0	0	0	0	0
19–24 Male	1.8	1	1	0	100.0	0	0	0
25–29 Female	5.4	1	3	66.7	33.3	0	0	0
25–29 Male	5.1	1	2	100.0	0	0	0	0
30–40 Female	4.3	1.6	8	62.7	27.5	0	0	0
30–40 Male	0.3	1.3	14	64.3	7.1	14.3	14.3	0
>40 Female	8.3	1.7	15	11.1	0	0	77.0	11.1
>40 Male	1.5	4	1	100.0	0	0	0	0

Note: Age in years at time of death. % = percentage; μ = average; NC = number of caries; O = occlusal; C = coronal; CC = cervical-coronal; CR = cervical-root; R = root.

Table 8.9. Formative Period Caries among Inland Groups

			Incidence					
Age/Sex	%	μ	NC	O	C	CC	CR	R
0–2	1.1	2.0	2	100	0	0	0	0
3–12	10.8	1.4	35	60	8.6	22.9	8.57	0
13–18 Female	8.4	1.4	11	100	0	0	0	0
13–18 Male	3.7	1.0	1.0	100	0	0	0	0
19–24 Female	17.8	1.4	19	63.2	0	0	36.7	0
19–24 Male	21	1.2	47	74.5	12.8	4.3	6.4	2.1
25–29 Female	10.3	1.5	11	27.3	0	45.5	27.3	0
25–29 Male	15	1.1	15	86.7	0	13.3	0	0
30–40 Female	32.8	1.5	90	51.1	8.9	4.4	31.1	4.4
30–40 Male	20.0	1.4	75	69.3	1.3	4.0	25.3	0
> 40 Female	12.8	1.6	14	35.7	0	0	50	7.1
> 40 Male	19.3	1.9	20	55.0	0	10	35	0

Note: Age in years at time of death. % = percentage; μ = average; NC = number of caries; O = occlusal; C = coronal; CC = cervical-coronal; CR = cervical-root; R = root.

Formative groups have a higher frequency of caries than Archaic groups have. This increment is more statistically significant when Formative inland and Archaic groups are compared (Tables 8.4 and 8.9; Archaic/inland Formative: subadults 0–2, z=-1.92, p=.03; subadults 3–12, z=-5.84, p=.00; females 13–18, z= -3.27, p=.00; males 13–18, z=-3.54, p=.00; males 19–24, z=-4.41, p=.00; females 25–29, z=-3.89, p=.00; males 25–29, z =-3.98, p=.00; females 30–40, z=-9.53, p=.00; males 30–40, z=-8.66, p=.00; females >40, z=-1.17, p=.12; males >40, z=-5.45, p=.00).

Most caries among coastal and inland groups are occlusal, but inland groups show a comparatively higher percentage of cervical caries. This is possibly the result of a diet rich in carbohydrates and/or severe alveolar resorption that exposed tooth roots to cariogenic activity. Some teeth presented more than one carious lesion, but the cariogenic index (CI) for coastal and inland groups is similar (coastal CI, 45/29=1.55; inland CI, 340/268=1.27).

Middle Horizon

The frequency of AMTL decreases during the Middle Horizon in some of the age-sex segments in comparison to the inland Formative groups. This reduction is statistically significant among certain age-sex segments (Tables 8.5 and 8.10; inland Formative/Middle Horizon: females 25–29, z=4.55, p=.00; males >40, z=6.84, p=.00).

No differences in the percentage of teeth with alveolar resorption were found between the inland Formative and Middle Horizon groups. However, the average degree of alveolar resorption is slightly lower for Middle Horizon groups, especially among individuals aged 25 years or older. The percentage of teeth with abscesses between inland Formative and Middle Horizon groups is also similar (Table 8.10); abscesses are rare and primarily located on buccal surfaces.

Middle Horizon groups show a percentage of teeth with dental wear, in each age-sex segment, similar to the inland Formative groups (Tables 8.7 and 8.11). The average degree of dental wear is slightly—but not significantly—lower among Middle Horizon groups. However, the shape of tooth wear changes, with a dramatic decrease in the frequency of the plane and a slight increase in the concave shape. Apparently, the foods consumed by the Middle Horizon groups were softer (Tables 8.7 and 8.11; inland Formative/Middle Horizon plane dental wear shape: subadults 0–2, z=4.51, p=.00; subadults 3–12, z=2.91, p=.02; males 13–18, z=4.25, p=.00; females 25–29, z=2.80, p=.03; males 30–40, z=3.08, p=.00).

The percentage of teeth with caries and the average size of the caries found among Middle Horizon groups is similar to what was observed among inland Formative groups. Some age-sex segments of the Middle Horizon, however,

Table 8.10. Middle Horizon Antemortem Tooth Loss, Alveolar Resorption, and Abscesses

	AMTL	**Alveolar Resorption**		**Abscesses**	
Age/Sex	%	%	μ	%	μ
0–2	0	65.9	1.4	0	0
3–12	0	88.9	1.7	0.1	3.0
13–18 Female	0	94.9	1.8	1.4	5.8
13–18 Male	0	91.9	1.7	0	0
19–24 Female	2.6	98.9	2.3	1.3	8.3
19–24 Male	4.1	97.8	2.6	0.7	2.5
25–29 Female	2.2	100.0	2.8	1.0	4.0
25–29 Male	3.4	99.1	2.8	0	0
30–40 Female	14.2	99.1	3.4	3.7	4.6
30–40 Male	8.8	99.7	3.7	3.2	4.5
>40 Female	44.1	100.0	4.3	7.7	4.9
>40 Male	17.9	100.0	4.1	8.4	5.7

Age in years at time of death. % = percentage; μ = average; AMTL = antemortem tooth loss.

Table 8.11. Middle Horizon Dental Wear

Age/Sex	%	μ	P	PC	C	R
0–2	25.4	2.2	38.2	61.8	0	0
3–12	69.5	3.0	14.1	84.1	1.8	0
13–18 Female	65.7	2.8	27.7	68.1	4.3	0
13–18 Male	78.0	2.7	5.2	91.9	2.9	0
19–24 Female	94.8	2.7	12.4	81.8	5.8	0
19–24 Male	90.9	2.9	16.5	79.8	3.7	0
25–29 Female	97.6	3.4	8.8	84.7	6.4	0
25–29 Male	97.9	3.2	16.3	83.7	0	0
30–40 Female	98.0	4.3	10.3	75.4	13.9	0.4
30–40 Male	99.2	4.3	9.6	81.9	8.2	0.3
>40 Female	99.1	4.7	3.2	80.8	13.4	2.6
>40 Male	99.6	4.9	3.4	82.9	11.4	2.2

Note: Age in years at time of death. % = percentage; μ = average; P = plane; PC = partially concave; C = concave; R = round.

show a statistically significant increase in teeth with caries (Tables 8.9 and 8.12; inland Formative/Middle Horizon: males 19–24, z=3.57, p=.00; females >40, z= 2.72, p=.00). There is also more variation in the location of the caries; most caries are on occlusal surfaces, but there is a comparatively higher percentage of caries on cervical and root surfaces among Middle Horizon individuals in comparison to Formative ones (Tables 8.9 and 8.12). These results contrast with the homogeneity seen in alveolar resorption between Middle Horizon and inland Formative groups and suggest that the cariogenic process may have been more aggressive among the former.

ENAMEL HYPOPLASIA

Archaic period

Among Archaic subadults, enamel hypoplasia (EH) is present in individuals aged 0–2 years. Adult females present EH in all age segments except for individuals over 40 years of age (Table 8.13). However, the sample for the latter age-segment is very small (n=9). In contrast, males show EH only in individuals aged 25 years and over (Table 8.14; females/males 19–24, z=-1.95, p=.03). Most enamel hypoplasias were formed when individuals were between 2 and 5 years of age (Table 8.14). Overall, Archaic groups show a low frequency of teeth with EH (<4 percent), and only one defect was identified in each affected tooth (PMHD=0).

Table 8.12. Middle Horizon Caries

Age/Sex	%	μ	NC	O	C	CC	CR	R
0–2	0.4	1.0	3	0	0	0	100.0	0
3–12	5.1	1.4	49	40.8	22.3	0	30.6	0
13–18 Female	8.3	3.3	7	50.0	16.6	8.3	25.0	0
13–18 Male	2.6	2.2	13	88.9	0	11.1	0	0
19–24 Female	13.9	1.6	47	59.6	0	6.4	31.9	2.1
19–24 Male	10.5	2.2	37	75.8	12.1	0	9.1	3.0
25–29 Female	14.7	1.3	24	66.7	0	0	29.2	4.2
25–29 Male	15.4	1.2	34	91.2	5.9	0	2.9	0
30–40 Female	25.0	1.8	178	38.8	3.4	5.6	43.8	8.4
30–40 Male	16.3	1.6	79	44.3	5.1	8.9	35.5	6.3
>40 Female	26.4	1.9	118	24.2	0.8	10.0	53.3	11.7
>40 Male	23.7	1.9	83	20.5	2.4	9.6	55.4	13.0

Age is in years. % = percentage; μ = average; NC = number of caries; O = occlusal; C = coronal; CC = cervical-coronal; CR = cervical-root; R = root.

Table 8.13. Percentage of Teeth with Enamel Hypoplasia

Age/Sex	Archaic %	F. Inland %	F. Coastal %	Middle Horizon %
0–2	1.5	3.4		2.8
3–12	0	2.6	0	6.2
13–18 Female	1.3	1.1	0	10.5
13–18 Male	0	7.7		14.1
19–24 Female	3.5	6.7	8.7	7.7
19–24 Male	0	21.4	1.9	9.4
25–29 Female	1.0	13.5	0	11.8
25–29 Male	2.8	1.8	0	7.1
30–40 Female	1.2	13.6	1.6	12.3
30–40 Male	3.3	7.8	3.0	10.0
>40 Female	0	1.9	3.3	10.5
>40 Male	1.9	1.7	0	8.8

Note: Age is in years. % = percentage; F. Coastal = Formative coastal groups; F. Inland = Formative inland groups.

Table 8.14. Age at the Time of Enamel Hypoplasia Formation

	Percentage by Age Category						
Sex	0–1	1–2	2–3	3–4	4–5	5–6	6–7
Archaic							
Undetermined	0	0	0	0	0	0	0
Female	0	0	0	40.0	60.0	0	0
Male	0	5.6	11.1	22.3	50.0	0	11.1
Total	0	4.4	8.7	26.1	52.1	0	8.7
F. Coastal							
Undetermined	0	0	0	0	0	0	0
Female	0	0	0	33.4	66.7	0	0
Male	0	0	20.0	40.0	40.0	0	0
Total	0	0	12.6	37.6	50.1	0	0
F. Inland							
Undetermined	16.7	0	83.3	0	0	0	0
Female	0	0	24.1	27.6	41.3	6.8	0
Male	1.4	8.1	31.5	13.7	38.4	6.8	0
Total	1.5	4.4	30.7	19.0	37.9	6.6	0
Middle Horizon							
Undetermined	0	16.7	66.7	16.7	0	0	0
Female	0	0.6	24.3	33.3	30.7	11.1	0
Male	2.9	8.5	25.4	31.6	27.1	4.0	0.6
Total	1.4	4.5	25.5	32.3	28.5	7.5	0.3

Note: Age is in years. F. Coastal = Formative coastal groups; F. Inland = Formative inland groups.

Formative period

Enamel hypoplasia is present in Formative inland individuals aged 0–2 years and above. No individuals aged 0–2 are available for the coastal Formative population. Inland individuals aged 3–12 years show EH in 2.6 percent of their teeth. No EH was found for this age-segment in the coastal population.

Among coastal Formative individuals, the percentage of teeth with EH is low (Table 8.13), and only one defect per tooth affected was identified (PMHD=0). Comparatively, inland Formative groups show a significantly higher percentage of teeth with EH (coastal/inland: males 19–29, z=-4.19, p=.00; females 25–29, z=-3.54, p=.00; males 30–40, z=-2.42, p= 0.01; females >40, z=-4.21, p=.00). Where coastal groups show a higher frequency of EH than do inland groups, the differences are not statistically significant. Multiple defects per tooth are identified for the first time among inland Formative groups (PMHD=36.5; Figure 8.2).

The peak for EH formation among Formative coastal groups is at 4–5 years of age, and the age range over which enamel hypoplasias formed is 2–5 years of age. Inland Formative groups show EH formation occurring between 0 and 6 years of age, with a peak at ages 4–5 (Table 8.14). Archaic and Formative coastal groups show a low frequency of EH, with a common peak at ages 4–5.

Figure 8.2. An example of severe mandibular hypoplasia in Individual 26 from Azapa-75 site in northern Chile.

Inland Formative groups show a higher percentage of teeth with EH than do Archaic groups (Tables 8.13 and 8.14; Archaic/inlandFormative: males 19–24, z=-4.46, p=.00; females 25–29, z= -3.65, p=.00; males 30–40, z=-2.27, p=.01). Estimation of individuals' age at the time of EH formation indicates that Formative inland groups were exposed to stressful events at an earlier age than Archaic and Formative coastal groups (Table 8.14).

Middle Horizon

Middle Horizon groups show a higher percentage of teeth with EH than inland Formative groups do. These differences are statistically significant in a few of the age-sex segments (Table 8.13; inland Formative/Middle Horizon: females 13–18, z=2.85, p=.00; females >40, z=2.05, p=.02). Multiple defects were identified in some affected teeth (PMHD=22.5). No other statistically significant differences were found between Middle Horizon and inland Formative groups. The peak age of enamel hypoplasia formation is 2–5 years (Table 8.14), which contrasts with one observed in inland Formative groups (4–5 years). This suggests that Middle Horizon individuals were exposed at an early age and throughout childhood to stressful events.

A higher frequency of EH may indicate either a lower or a higher health status (Wood et al. 1992), since different rates of EH can reflect differential survival of stress episodes. Life expectancy tables were used to evaluate this possibility.

LIFE EXPECTANCY

Life tables (Tables 8.15 and 8.16) indicate that the lowest life expectancy at birth corresponds to Formative inland groups, followed by the Middle Horizon groups. In contrast, the highest life expectancy at birth corresponds to Formative coastal groups, followed by Archaic hunter-gatherers. In addition, Formative inland and Middle Horizon individuals by age 25 show the lowest life expectancy and survivorship rates. In fact, the survivorship rate among Formative inland and Middle Horizon individuals is dramatically lower than that among Archaic and Formative coastal groups (Tables 8.15 and 8.16). Thus, life expectancy among Middle Horizon individuals was slightly higher than that observed among inland Formative individuals but lower than that observed among coastal groups of the Archaic and Formative period.

Discussion

Three different aspects—dental health, stress (as evidenced by EH), and life expectancy—of the adoption of agriculture in northern Chile were evaluated in this study. Dental health after the adoption of agriculture deteriorated because of a higher intake of carbohydrates, as evidenced by the increased percentage of teeth with caries, AMTL, and the changed patterns of dental wear. Concomitantly, the decline in the average degree of dental wear suggests that food textures became softer as a result of changes in both the foods consumed and cooking techniques (introduction of pottery as cookware).

The analysis of enamel hypoplasia indicates that the adoption of agriculture resulted, overall, in more-stressful conditions and a lower quality of life. The percentage of teeth with EH as well as the number of teeth with multiple defects among Formative inland groups show that the quality of this adaptation was lower than the Archaic one. Compared to the inland Formative, some age-sex segments of the Middle Horizon show a higher percentage of teeth with EH, but the frequency of multiple lesions is lower.

Life expectancy decreased among Formative inland groups but increased among coastal Formative ones, in comparison with the Archaic. The use of life expectancy tables has been questioned by some researchers (Bocquet-Appel and Masset 1996; Hoppa 2002; Hoppa and Vaupel 2002; Konigsberg and Frankenberg 2002) because changes in the values may actually reflect differences in fertility rather than mortality (Buikstra et al. 1986; Wood et al. 1992; Wood

Table 8.15. Life Expectancy Table for the Archaic and Coastal Formative

	Archaic							Coastal Formative						
Age	Dx	dx	lx	qx	Lx	Tx	ex	Dx	dx	lx	qx	Lx	Tx	ex
0	19	17.43	100.0	0.17	456.4	2543.58	25.28	3	3.85	100.0	0.04	490.4	3179.49	31.79
5	9	8.26	82.57	0.10	392.2	2087.16	22.81	5	6.41	96.15	0.07	464.7	2689.10	27.97
10	4	3.67	74.31	0.05	362.4	1694.95	18.86	0	0	89.74	0	448.7	2224.36	24.79
15	5	4.59	70.64	0.06	341.7	1332.57	15.00	3	3.85	89.74	0.04	439.1	1775.64	19.79
20	3	2.75	66.06	0.04	323.4	990.83	10.54	4	5.13	85.90	0.06	416.7	1336.54	15.56
25	12	11.01	63.30	0.17	289.0	667.43	7.24	8	10.26	80.77	0.13	378.2	919.87	11.39
30	18	16.51	52.29	0.32	220.2	378.44	4.42	13	16.67	70.51	0.24	310.9	541.67	7.68
35	24	22.02	35.78	0.62	123.9	158.26	2.50	27	34.62	53.84	0.64	182.7	230.77	4.29
40	15	13.76	13.76	1.00	34.40	34.4	25.28	15	19.22	19.22	1.00	48.1	48.08	2.50

Note: Age is in years. Dx: number of individuals; dx: percentages of death; lx: percentage of survivors; qx: probability of death; Lx: total number of years lived by the individuals in that interval; Tx: total number of years remaining in the lifetime of all the individuals in that interval; ex: life expectancy.

Table 8.16. Life Expectancy Table for the Inland Formative and Middle Horizon

	Inland Formative							Middle Horizon						
Age	Dx	dx	lx	qx	Lx	Tx	ex	Dx	dx	lx	qx	Lx	Tx	ex
0	19	15.70	100.0	0.16	460.7	2303.72	23.04	43	19.72	100	0.2	450.7	2314.22	23.14
5	21	17.36	84.30	0.21	378.1	1842.98	21.86	25	11.47	80.28	0.14	372.7	1863.53	23.21
10	0	0	66.94	0	334.7	1464.88	21.88	11	5.05	68.81	0.07	331.4	1490.83	21.67
15	9	7.44	66.94	0.11	316.1	1130.17	16.88	12	5.50	63.76	0.09	305.0	1159.40	18.18
20	13	10.74	59.50	0.18	270.7	814.05	13.68	24	11.01	58.26	0.19	263.8	854.36	14.67
25	9	7.44	48.76	0.15	225.2	543.39	11.14	14	6.42	47.25	0.14	220.2	590.60	12.50
30	14	11.57	41.32	0.28	177.7	318.18	7.70	17	7.80	40.83	0.19	184.6	370.41	9.07
35	20	16.53	29.75	0.56	107.4	140.50	4.72	27	12.39	33.03	0.38	134.2	185.78	5.63
40	16	13.22	13.22	1.00	33.1	33.06	2.50	45	20.64	20.64	1.00	51.6	51.61	2.50

Note: Age is in years. Dx: number of individuals; dx: percentages of death; lx: percentage of survivors; qx: probability of death; Lx: total number of years lived by the individuals in that interval; Tx: total number of years remaining in the lifetime of all the individuals in that interval; ex: life expectancy.

et al. 2002). Thus, a decrease in life expectancy, like the one seen among Formative inland groups in this study, could correspond to an increase in fertility, which would be congruent with the archaeological record. However, although the increase in EH among inland populations could reflect an increase in survivorship of stressful events, permanent settlement associated with changes in food production probably increased the risk among these groups, which resulted in higher frequencies of EH.

In coastal Formative groups, the increase in life expectancy cannot—based on the archaeological record—be interpreted as a decrease in fertility. Indeed, studies conducted in similar coastal populations from Peru have also shown that the incorporation of cultigens in the diet was beneficial (Benfer 1990), which is in agreement with our results for EH.

Middle Horizon groups show an increase in life expectancy and a higher number of teeth with EH when compared with inland Formative groups. Although an increase in life expectancy could be interpreted as a decrease in fertility, the archaeological record shows an increase in the number of settlements in the valley at this time. A higher number of EH but a lower PMHD may actually indicate a higher survival accompanied by a decreased number of stressful events.

In spite of these interpretational difficulties, there seems to be a decrease in the quality of life among inland groups but not among coastal ones after the adoption of agriculture (Formative period). Although it is possible to identify a major trend among these groups, it is also evident that the corresponding success of agricultural adaptations changed through time, which highlights the variability that this process can have in both space and time, even among groups that lived only thirteen kilometers apart.

Acknowledgments

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9

Population Plasticity in Southern Scandinavia

From Oysters and Fish to Gruel and Meat

PIA BENNIKE AND VERNER ALEXANDERSEN

In most of Europe, Mesolithic hunting, fishing, and gathering was followed by Neolithic agriculture and husbandry. It is not clear whether or to what extent Mesolithic populations were pushed out by immigrants (the demic expansion theory), or whether through diffusion they adopted agriculture, their genetic pool remaining more or less unchanged. Many studies involving DNA and skeletal morphology to explore the problem have produced contradictory results (Ammermann and Cavalli-Sforza 1984; P. Rowley-Conwy 1985; Petersen 1988, 1992; Harding et al. 1989; Cavalli-Sforza et al. 1994; Barbujani et al. 1995; Richards et al. 1996; Nørby and Saillard 1998; Zvelebil 1998; Semino et al. 2000; Crubézy et al. 2002; Fischer 2003).

Scandinavian Climate and Fauna

Most of Scandinavia was covered with ice during the Weichselian glaciation. In Denmark, the ice disappeared completely around 13,000 BP, and Paleolithic hunting parties came to southern Scandinavian regions following reindeer herds. A rise in temperature circa 11,500 BP brought bison, wild horses, and aurochs to the region, and somewhat later, red deer and wild boar. Birch and pine forests were later supplemented by lime (linden), elm, and oak.

Archaeology: Mesolithic

The chronology of Mesolithic cultures between circa 11,000 and 6000 BP includes (in rough order) the Maglemose, Kongemose, and Ertebølle cultures (Jensen 2001; Larsson 1990; see Table 9.1). The well-known Mesolithic kitchen middens of southern Scandinavia were associated with small camps of huts. The middens contain shells of oysters, cockles, mussels, and periwinkles. Oyster shells are most common in early middens. In the late part of the Mesolithic (Ertebølle), cockles became most common. At inland sites, hunting was common, but whalebones and oyster shells showed that inland communities

Table 9.1. Cultural Periods, with Inclusive Dates

Culture Group	Date Range	Period
Maglemose Culture	11,000–8400 BP	Mesolithic
Kongemose Culture	8400–7400 BP	Mesolithic
Ertebølle Culture	7400–5950 BP	Mesolithic
Early Funnel Beaker Culture	5950–5200 BP	Early Neolithic
Late Funnel Beaker Culture	5200–4800 BP	Middle Neolithic A
Battle Axe Culture	4800–4300 BP	Middle Neolithic B
Late Neolithic	4300–3700 BP	Late Neolithic

maintained a connection with the coast. Remains of various nuts have been found throughout southern Scandinavia. Throughout most of the Mesolithic, hunting focused on red deer, roe deer, marten, and wild boar (Larsson 1990), but fish contributed more to the diet. Shoreline settlements, dugout canoes, fishing equipment, and bones of fish and seals suggest primary dependence on marine food. The most recent rise in the fluctuating sea level occurred between 6400 and 6100 BP. Shoreline camps followed rising sea levels and are located well inland from the modern shoreline.

Archaeology: Neolithic

The Early Neolithic Funnel Beaker Culture brought important social change. Several groups can be recognized through their material symbols, adapted to different parts of the "cultural package." They seem to have had approximately the same economy, a mixture of Neolithic strategies including hunting and fishing. Traces of violence visible on skeletons suggest that small family clans were at war with one another; nevertheless, family clans apparently were held together by networks of exchange, marriages, and friendships. As groups grew, competition for land increased.

Diet: Mesolithic

Stable isotopic studies ($\delta^{13}C$) have shown that the protein content in the diet during the Late Mesolithic period (8600–7200 BP) lay between -17 and -13 ‰, derived mainly from marine food. A dramatic change to terrestrial diet probably occurred between 6800 and 5950 BP, reflected by levels between -19 and -21 ‰ (Tauber 1986). The $\delta^{15}N$ content of the bones distinguishes a carnivore diet (values of 10–11 ‰) from a vegetarian diet (values of 5–6 ‰). Humans with diets high in freshwater fish may have $\delta^{15}N$ values of 12–15 ‰. Danish skeletal material from Mesolithic coastal sites reveals $\delta^{15}N$ values from 8 ‰ to 14 ‰ (Richards and Koch 2001).

Diet: Neolithic

Neolithic communities appeared circa 6000 BP, concomitantly with falling temperature and sea level and a decrease in the daily tide, changing the salt content of the seawater and, consequently, fishing patterns. Oysters probably disappeared. Elm tree disease thinned forests circa 5900 BP, facilitating the introduction of domesticated cattle, sheep or goats, and pigs, but hunting and fishing and collecting remained important. Traces of Early Neolithic agriculture in Denmark are sparse. Cattle and pigs seem to have provided most of the meat. During the time of the Funnel Beaker Culture, pottery enabled food to be softened through cooking; as a result, soup and gruel became important in the diet. Pottery also allowed food storage, possibly altering social structure. The ^{15}N isotope values during the Neolithic ranged from 7 ‰ to 10 ‰, suggesting a diet of vegetables and meat and small amounts of freshwater fish. Some farmers, particularly the Pitted Ware Culture in Gotland, may even have reverted to a diet dominated by marine food.

Human Skeletal Remains from Southern Scandinavia

The few known early Mesolithic skeletons exhibit considerable variation. They cover a large area and a long time span. Most are individual finds from separate regions (Holmegård, Køge Bugt). Multiple burials are known only in the later Mesolithic and are associated with the Kongemose and Ertebølle cultures. The Late Mesolithic site of Bøgebakken, Vedbæk, at around 7000 BP produced 22 individuals in 17 graves (Albrethsen et al. 1976). Two sites at Skateholm in southern Sweden have been excavated, yielding 65 and 22 graves containing 47 and 21 human skeletons, respectively: Skateholm I (circa 6900 BP) produced 43 adults and 4 children under eleven years old; Skateholm II (circa 7200 BP) produced 17 adults and 4 children under seven years old (Larsson 1990; Jensen 2001).

Uncremated Mesolithic skeletal remains from Denmark represent at least 68 individuals, ranging from excellent to very poor in preservation (Table 9.2). Around 21 percent of the skeletons were those of children and 7 percent were adolescents. Of the sexed adults, 65 percent were males and 35 percent were females.

Radiocarbon dating of museum collections (approximately fifty discrete skeletons) increased the sample of Early Neolithic Danish skeletal remains considerably. These remains were found under a variety of circumstances, including simple inhumation graves, barrows with timber structures, and megalithic tombs (dolmens).

Early Neolithic skeletons represent at least sixty individuals of varying pres-

Table 9.2. Sex and Age Distribution of Danish Mesolithic and Early Neolithic Skeletons

	Mesolithic N(%)	Early Neolithic *N* (%)
Sex distribution		
Males	24 (59%)[a]	29 (71%)[a]
Females	17 (41%)[a]	12 (29%)[a]
Undetermined sex	18	10
Age distribution		
Children		
Infant I (< 6 years)	11	4
Infant II (6/7–12/14 years)	3	5
Total children	14 (21%)	9 (15%)
Adolescents (12/14–18/20 years)	5 (7%)	15 (25%)
Adults		
Young adult (18/20–35/40 years)	16	13
Middle adult (mature) (35/40–55/60 years)	17	17
Old adult (> 55/60 years)	2	0
Undetermined age	14	6
Total adults	49 (72%)	36 (60%)
Total number of individuals	68	60

[a] = percentage of sexed skeletons.

ervation (Table 9.2). Of this sample, 15 percent were children under the age of 12 and 25 percent were adolescents. Of the sexed skeletons, 70 percent were males and 30 percent females.

For the following Middle/Late Neolithic periods (*N*=966), 13 percent of the skeletons were those of children. Of these, 57 percent were under seven years old, and 8 percent were juveniles. Adult skeletons were 60 percent male to 40 percent female (Bennike 1985).

Several Early Neolithic skeletons came from bogs. Bog bodies are usually well preserved but may lack certain body elements. Good preservation of this material may account for the relatively high ratio of subadults to adults that has been found. The skeletons from the Middle/Late Neolithic are mainly from large megalithic graves, each containing up to one hundred individuals (Bröste et al. 1956). Protected from weathering, the skeletons were reasonably well preserved. The samples are not amenable to demographic analysis.

Morphology

Mesolithic European skeletons are robust. The walls of cranial vaults and the shafts of the long bones are thick. Most skulls are dolichocephalic or mesocephalic; a few are brachycephalic. Facial skeletons display a variety of forms. Low and broad skulls were common in eastern Europe; high and narrow skulls

were common in Mediterranean areas. Northern European skulls were intermediate in form (Roth-Lutra 1967).

Brow ridges become less prominent through time, probably reflecting declining chewing pressure. However, this explanation may not be correct. Experiments have found no definite correlation between the two. Instead, brow ridges seem to be part of a complicated growth pattern involving the shape of the face and skull (Moss and Young 1960; Enlow 1982; Lahr 1996).

Three main hypotheses have been proposed to explain the thickness of the cranial vault (Liebermann 1996). One is that thick cranial vaults reflect natural selection minimizing the risk of injury. The relatively recent decline in thickness may reflect relaxation of selection pressure. The second theory is that differences in cranial vault thickness reflect plastic responses to muscular forces in chewing. Some Mesolithic vaults are keel shaped and slightly rounded at the top, which means that the parietal bones slope up towards the midline of the skull, where the bone often is thicker. The shape may be related to the development of temporal (chewing) muscles (Brown et al. 1979; Lahr 1996; Liebermann 1996). The third theory is that physical exercise, influencing levels of growth hormone and bone-forming cells, could affect cranial vault thickness. Both Liebermann (1996) and Churchill (1998) suggest that a thicker vault and a thicker cortex in the limb bones and the rest of the skeleton reflect a high level of physical exercise from early childhood on (see also Ruff et al. 1984). The three theories, of course, are not mutually exclusive. The trends may reflect components of all three.

A sturdy body build was advantageous in the cold climate of the Upper Paleolithic, when hunting technology emphasized strength. A body adapted to cold is compact, with short limbs; the skull is relatively large and heavy. Strong individuals and aggressive behavior may have been favored under these conditions.

The overall size of the human body decreased during the Upper Paleolithic, 35,000–11,000 years ago, and the Mesolithic (Frayer 1984). The trend may be a result of declining natural selection favoring size and strength, because dangerous spear hunting of large animals declined with the invention of the bow and arrow, and the need for cooperation and experiential learning became more advantageous than size and strength (Kull 1990). Nevertheless, robust skeletons genetically selected earlier in prehistory were slow to change.

Pronounced muscular attachments on prehistoric skeletons reflect lifelong physical exertion, not short-term "body building" (Ruff et al. 1984). The transition from robust to gracile build between the Paleolithic and the Neolithic was greater in men (approximately 5 percent) than in women (approximately 3 percent), so sexual dimorphism declined, possibly because men's activities changed more than those of women (Frayer and Wolpoff 1985). Men's teeth

also decreased more in size than women's (Frayer 1978, 1984). These gender differences are modest in modern populations and certainly less distinct than in Upper Paleolithic populations.

Skeletons from the Danish Mesolithic and Neolithic clearly differ from one another. Early Neolithic individuals are generally shorter and more gracile, and their teeth are smaller. This trend in size is reversed during the Middle and Late Neolithic periods, with average stature again becoming larger. The metric skull changes may reflect reduced chewing stress. Such changes are common during the transition to agriculture in some areas. (The opposite trend has also been observed; in southeastern Europe, for example, the breadth of the skull increased during the transition [Krenzer 1996].) Some of the Neolithic skulls seem to have higher and narrower faces than Mesolithic skulls. Although few brachycephalic skulls are found among the Danish Mesolithic remains (Hansen et al. 1972; Albrethsen et al. 1976), they are more common in the Neolithic (Schwidetzky and Rösing 1989; Bröste et al. 1956). The shape of the skull, however, is largely dependent on heritable factors, so the change may reflect absorption of immigrant groups into the population; the Mesolithic groups nonetheless retained their genetic integrity, so the fact that both gracile and robust skulls appear in the Middle and Late Neolithic is not surprising. Several robust skulls in southern Sjælland buried in megaliths may represent members of local family graves. Six of twenty-five skulls from a passage grave in Borreby were brachycephalic (Virchow 1870; Nielsen 1906; Bröste et al. 1956).

Measurements of Danish skeletal material follow the general trend. Skull dimensions decreased from the Mesolithic to the Early Neolithic but increased during the Neolithic, a trend that despite small samples apparently follows the same pattern in males and females (Figure 9.1a–e). However, the length of male skulls remained unchanged in the Mesolithic and Early Neolithic, while length decreased in female skulls. The opposite happened from the Early Neolithic to the Late Neolithic: the length of the male skulls decreased, while that of females remained stable. Indices of cranial length/breadth follow the same pattern as the majority of the cranial measurements. The height/length index shows that the skulls became more dolichocephalic and lower from the Mesolithic to the Early Neolithic but became more brachycephalic towards the end of the Late Neolithic. The length/breath skull index is the same in the Mesolithic and the Late Neolithic, whereas the skull height decreased in relation to its length.

Decreasing robusticity involved a decrease both in epiphyseal breadth and in circumference/length indices on most of the long bones (Figure 9.2a–h). The length of some of the long bones decreased slightly or not at all during the Early Neolithic; length definitely increased towards the Late Neolithic period.

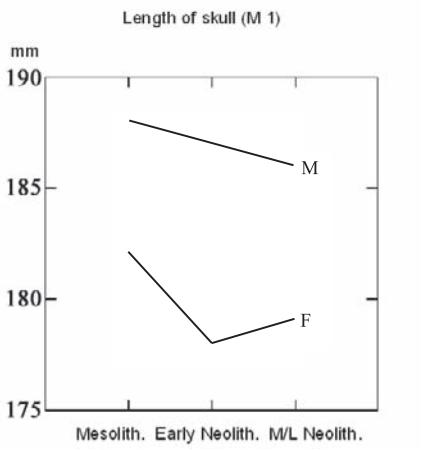

Figure 9.1a. Length of skull (M1) in Scandinavian populations.

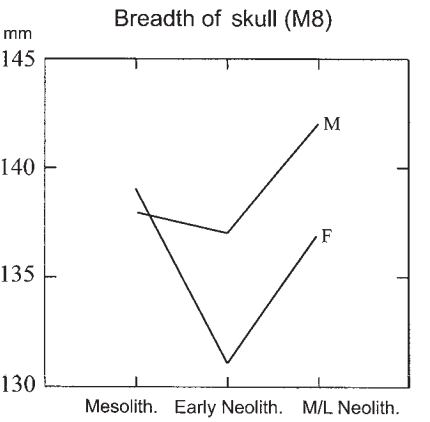

Figure 9.1b. Breadth of skull (M8) in Scandinavian populations.

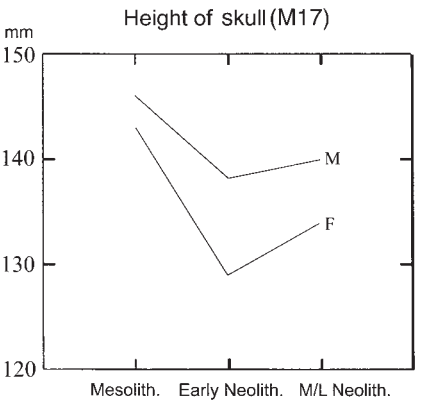

Figure 9.1c. Height of skull (M17) in Scandinavian populations.

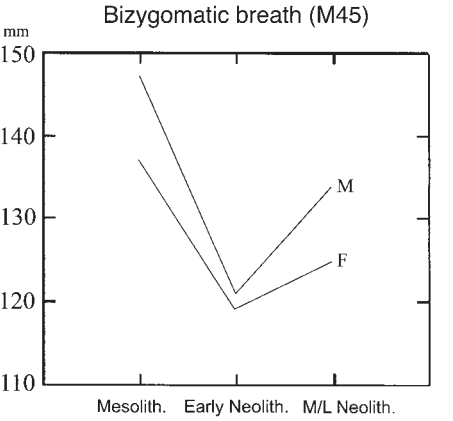

Figure 9.1d. Bizygomatic breadth (M45) in Scandinavian populations.

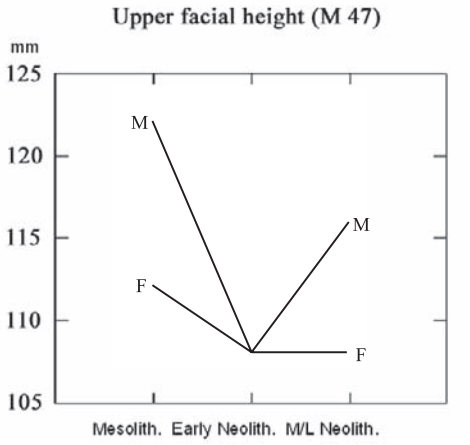

Figure 9.1e. Upper facial height (M47) in Scandinavian populations.

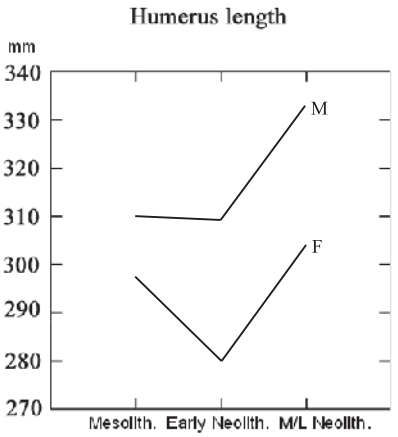

Figure 9.2a. Humerus length in Scandinavian populations.

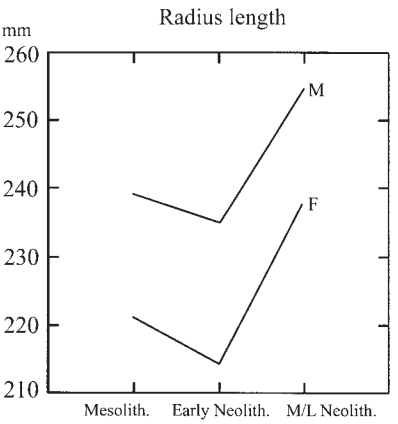

Figure 9.2b. Radius length in Scandinavian populations.

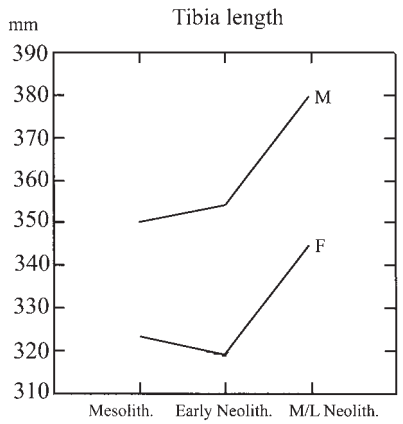

Figure 9.2c. Tibia length in Scandinavian populations.

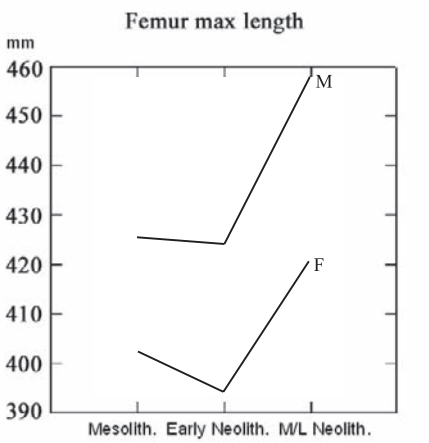

Figure 9.2d. Maximum femur length in Scandinavian populations.

Mesolithic limb bones are rather short and stout with large protuberances, prominent areas of muscle attachment, thick cortical area, and small medullary cavities. The bones are sometimes slightly curved, as a result not of low calcium content but of extensive muscle activity. In general, bone mass and mineral content values from the Middle and Late Neolithic are higher than in modern populations (Ruff 1992; Bennike and Bohr 1990).

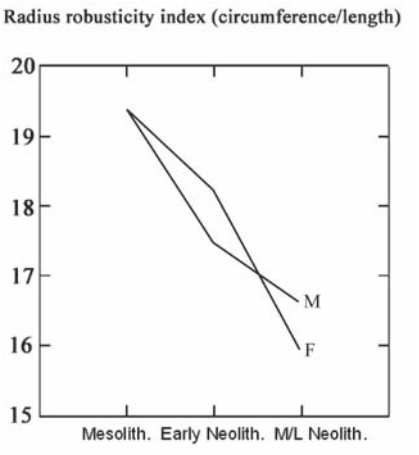

Figure 9.2e. Radius robusticity index (circumference/length) for Scandinavian populations.

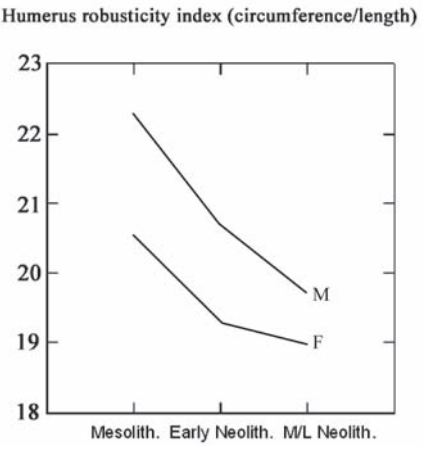

Figure 9.2f. Humerus robusticity index (circumference/length) for Scandinavian populations.

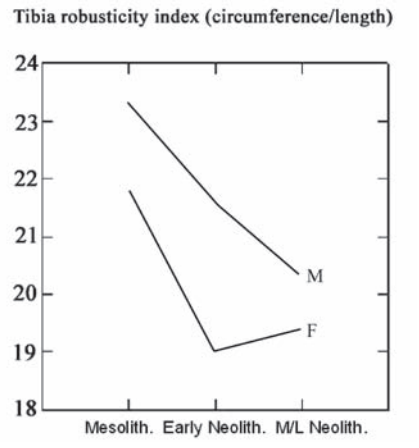

Figure 9.2g. Tibia robusticity index (circumference/length) for Scandinavian populations.

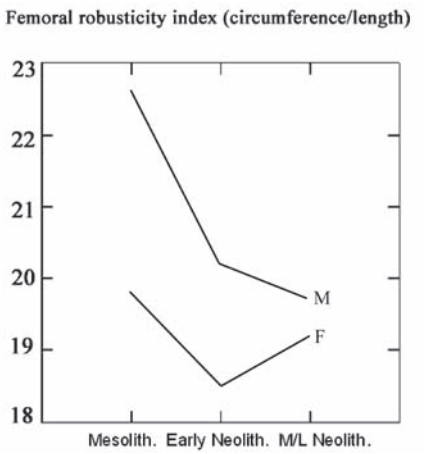

Figure 9.2h. Femoral robusticity index (circumference/length) for Scandinavian populations.

Dentition

In a hunter-fisher-gatherer population, such as the populations in southern Scandinavia whose diet was highly dependent on marine food, the expected pattern is severe attrition and a low caries rate; abscess formation is attributable to excessive wear, with little if any loss of teeth antemortem. Populations that live on a mixture of pastoralism or fishing and agriculture exhibit somewhat less attrition and a low rate of caries. Abscesses are primarily attributable to excessive wear, and antemortem tooth loss is low to moderate. Mixed farming or intensive horticulture is likely to be associated with less attrition but severe antemortem tooth loss, showing more caries and with abscessing attributable to caries (Littleton and Fröhlich 1993). The Meso-Neolithic Danish skeletal material corresponds perfectly to these expectations as the diet changed from one dependent on marine food and some carbohydrate-rich plant foods to a diet based on a mixture of meat, fish, vegetables, and cereals. During the later Neolithic, the model of pastoralism and agriculture also fits the observations.

ENAMEL HYPOPLASIA

A stressful daily life for weaned children is reflected in a high frequency of linear enamel hypoplasia (LEH) in both the Late Mesolithic and Early Neolithic periods, but the frequency of LEH diminished during the Middle and Late Neolithic periods (Table 9.3). Other than one wide, horizontal depression suggesting a long period of stress in one individual, linear enamel hypoplasias are narrow on Late Mesolithic teeth, indicating short disturbances of enamel formation. In all cases, the disturbances appeared to be mild. Most often the canines were affected with one or more linear enamel hypoplasias. In the Mesolithic samples from Skateholm, both premolars and canines (35 percent) were involved more often than canines alone (15 percent). In the Early Neo-

Table 9.3. Frequency of Enamel Hypoplasia

	Individuals	
	Aff./Obs.	%
Late Mesolithic Period		
Danish sites	18/29	62.1
Skateholm II (Scania)	7/16	43.8
Skateholm I (Scania)	16/24	66.7
Early Neolithic Period		
Danish sites	12/19	63.2
Middle and Late Neolithic Periods		
Danish sites	58/144	40.3
Modern Danes (1976)	16/104	15.4

Note: Aff. = individuals affected; Obs. = individuals observable; % = percentage.

lithic sample from Denmark, the anterior teeth, the premolars, and the canines were often involved.

Enamel hypoplasia of the LEH type restricted to the facial surfaces of permanent canines could be attributable to local nutritional problems or lack of space in the jawbones, but the presence of several affected teeth often reflects serious disease. Already during the Late Mesolithic period, increased contacts between the various groups of people promoted the risk of spreading contagious diseases. The cold, damp winter season and frequent visits to the same sites (with their accumulated refuse) added to the risk of serious disease. LEH formation of incisors, canines, and premolars suggests that stresses occurred among children 2.5–6 years old.

TOOTH SIZE

The general evolutionary trend during the Pleistocene from large to smaller teeth has recently been studied by Ahlström (2003) in relation to the Mesolithic-Neolithic transition. Using a principal component analysis of twenty-eight Mesolithic, Neolithic, and modern samples from various parts of Europe, Ahlström showed a decrease in general tooth size over time and especially a reduction of the anterior teeth. A change in the proportions of several teeth also occurred. The Neolithic teeth generally had smaller faciolingual crown diameters than those from the Mesolithic period.

The deciduous and permanent teeth of Danish Late Mesolithic people were almost the same size as today. The Late Mesolithic teeth belonged to individuals from different parts of Denmark. Teeth from Jutland were smaller than teeth from the eastern part of Denmark and particularly those from eastern Zealand. However, some reduction in size occurred in the Early Neolithic period (Table 9.4).

Of the very few deciduous teeth from the Late Mesolithic and Neolithic periods that have been found in Denmark, deciduous molars from the Late Mesolithic period are of modern size, whereas those from the Early Neolithic period are distinctly smaller. The size increases again for teeth from the Middle and Late Neolithic periods.

Reduction in crown size of permanent teeth is also observed for the Early Neolithic period in various parts of Denmark, although the reduction is significant for only a few molar dimensions. In the following Middle Neolithic period, increased tooth size was observed in the small sample of teeth. By the Late Neolithic period, teeth had returned to a size similar to that of the Late Mesolithic (Figure 9.3a–b).

The initial reduction could reflect relaxed natural selection for large teeth as part of ongoing reductions in the cranial vault and jaws temporarily associated with the introduction of the new lifestyle. The smaller teeth could also be a

Table 9.4. Tooth Crown Size in Various Populations

	Sum of I1 & I2	Sum of C–M2	Sum of I1–M3	Source
Late Mesolithic Period				
Skateholm II	205.94	882.02	1302.45	Alexandersen 1988
Skateholm I	183.65	821.12	1201.97	Alexandersen 1988
Danish sites	170.29	817.12	1196.44	Present study
Early Neolithic Period				
Danish sites	166.29	766.76	1126.73	Present study
Middle and Late Neolithic Periods				
Danish sites (MN/LN)	177.67	823.08	1206.93	Present study
Swedish sites				
Rössberga (MN)	165.14	790.95	1154.02	Ahlström 2003
Visby-Västerbjers(MN)	164.02	780.68	1133.29	Ahlström 2003
Bedinge (Battle Axe)	186.90	829.85	1229.20	Alexandersen 1989
Belgian sites				
Neolithic site	168.30	755.52	1101.49	Brabant 1971
Switzerland, Slovakia				
Neolithic sites (Barmaz I & II, Chamblandes, Krskrany)	164.21	760.05	1108.71	Frayer 1978

Note: Tooth crown size is measured as length multiplied by breadth (mm^2).
I1 = first incisor; I2 = second incisor; C = canine; M2 = second molar; M3 = third molar; MN = Middle Neolithic; LN = Late Neolithic.

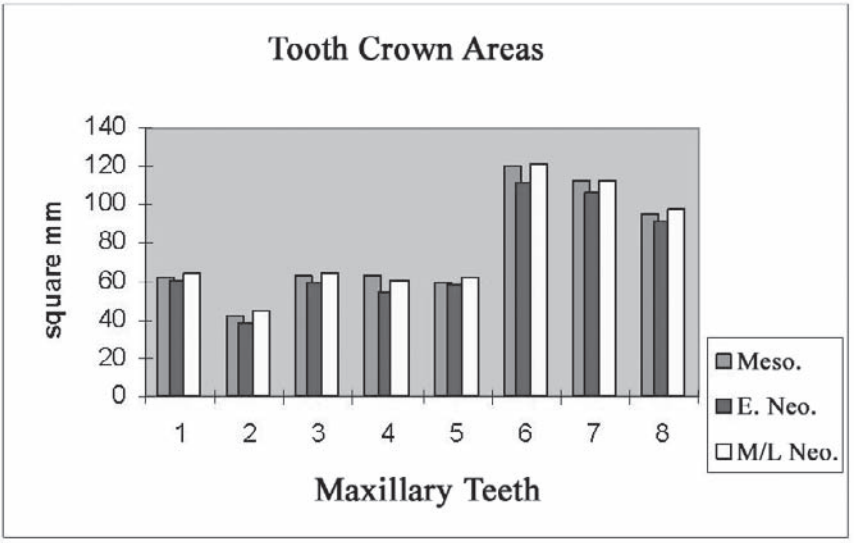

Figure 9.3a. Tooth crown areas (maxillary) in Scandinavian populations.

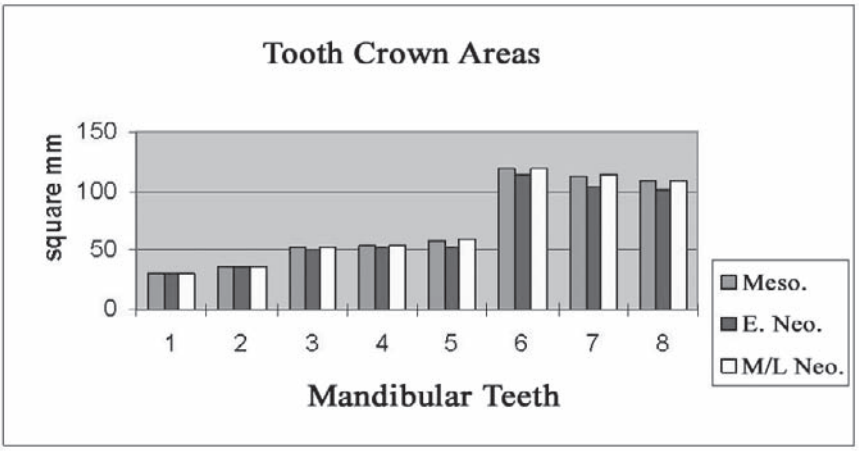

Figure 9.3b. Tooth crown areas (mandibular) in Scandinavian populations.

result of contact and interbreeding between large-toothed Mesolithic hunters and gatherers and pioneer groups of agriculturalists with smaller teeth from northern Germany or Poland, reflecting genetic or long-standing dietary differences. Their teeth were smaller than Nordic Mesolithic and Middle and Late Neolithic teeth from various parts of Europe (Berbig and Seifert 1975; Brabant 1971; Frayer 1978; Alexandersen 2003).

Reduced tooth size in the Early Neolithic might also reflect poor adaptation to a new lifestyle. The small size of Early Neolithic deciduous molars, which develop before birth and very early in childhood, suggests that some mothers lived stressful lives and that some children had a low fetal growth rate, were likely to have a low birth weight, and may have died at a young age. The fact that first molars, late-forming molars, and some anterior teeth also declined in size may indicate that some children had problems acquiring enough food to match their energy expenditure. When the Danish population subsequently became fully adapted to farming and husbandry during the Middle/Late Neolithic, the tooth size increased to a similar or even larger tooth size than in contemporary Neolithic Swedish and German groups (Table 9.4).

DENTAL CARIES

Caries were nonexistent in the Late Mesolithic period in Danish and Swedish skeletal material (Table 9.5). In the Early Neolithic, caries were found in 6 out of 21 individuals with at least seven cheek teeth preserved (28.6 percent): 1 of 2 juveniles, 2 of 11 young adults, and 3 of 8 older individuals had one or more teeth with dental caries. Only 1 person had five teeth with decay. The frequency of antemortem tooth loss was low, and mature individuals probably

Table 9.5. Frequency of Dental Caries

	Individuals		Teeth		
	Aff./Obs.	%	Aff./Obs.	%	Source
Denmark					
Mesolithic Period					
Vedbæk	0/22		0/357		
Various other sites	0/16		0/316		
Early Neolithic	6/21	28.6			
Middle Neolithic	7/28	25.0			
Late Neolithic	14/94	14.9			
Sweden					
Meso. Skateholm			5/1339	0.4	Alexandersen 1988
MN Rössberga			46/1375	3.3	Ahlström 2003
MN Västerbjers			0/696		Ahlström 2003
MN Visby			0/511		Ahlström 2003
MN Bedinge			1/19	5.3	Alexandersen 1989
MN/LN			14/386	3.6	Holmer & Maunsbach 1956
Germany					
Middle Elbe–Saale Region Banded Ware Culture and Corded Ware Culture					
Early Neolithic	112/184	60.9			Finke et al. 2002
Middle Neolithic	39/76	51.3			
Late Neolithic	327/584	56.0			
Poland					
Malopolska					
Funnel Beaker Culture	3/31	9.7	3/271	1.1	Haduch 2002

Note: Aff. = affected; Obs. = observable; % = percentage; Meso. = Mesolithic; MN = Middle Neolithic; LN = Late Neolithic.

suffered tooth loss because of excessive wear, trauma, or periodontal disease rather than because of caries.

The frequency of caries in the Danish Early Neolithic is lower than in the Banded Ware and Corded Ware mid-German cultures from the Early, Middle, and Late Neolithic, but it is comparable to the incidence in Polish Funnel Beaker groups (Table 9.5). The very moderate incidence of dental caries in Denmark and Sweden during the Neolithic period suggests that cereal consumption there was modest.

Among the small sample from the Middle Neolithic, 7 of 28 individuals (25.0 percent) with at least seven cheek teeth available for study had at least one tooth with a cavity. The sample consisted of individuals from megalithic graves on Funen and Zealand (Klokkehøj, Kyndeløse, Svinø, and Bidstrup). As in the Middle Neolithic, the frequency of caries in the Late Neolithic was rather low; one or more cavities were found in 30 of 106 individuals (28.3 percent).

DENTAL ATTRITION

Wear of the anterior permanent teeth decreased during the Mesolithic-Neolithic transition in Danish samples. The use of anterior teeth as a tool became less prevalent (Alexandersen 1988). A high level of attrition was still found on the premolars and molars in the Early Neolithic despite the cranial changes towards a narrower face, suggesting a decline in masticatory force. The smaller and narrower dental arches in the more gracile agriculturalists led to a change in the molar wear plane pattern, although the wear gradient from the first to second molars remained the same. Oblique wear on molars of agriculturalists has been contrasted with the more horizontal wear among hunters/gatherers (Smith 1984). In Danish and Swedish samples from Late Mesolithic and various Neolithic periods, higher grades of attrition of the first molars (grade 6–8, according to Smith 1984) were most common in the Late Mesolithic period, with a frequency of 0.69 (n=91). After that the rate declined: Early Neolithic period, 0.46 (n=28); Middle Neolithic period, 0.40 (n=19); and Late Neolithic period, 0.38 (n=38). The age compositions were the same in the samples (Alexandersen 1989).

The change from a marine-based diet to a terrestrial diet is not easy to detect in the macro wear. A change in food preparation techniques for a diet of soft, clean food should result in micro wear with fewer pits and finer scratches on occlusal facets. The heavy attrition found in the earlier Danish samples was probably caused by the consumption of unwashed vegetables and roots with phytoliths in some vegetables and cereals, as well as fine abrasive particles of minerals left in flour after grinding.

DENTAL DISEASES

Heavy wear of teeth or caries occasionally led to pulp infection and necrosis of the pulpal tissues. Chronic abscesses, often invisible to the naked eye, formed in jawbones. The frequency of abscesses remained the same from the Late Mesolithic to the Early Neolithic, but there is more antemortem tooth loss in the Early Neolithic for the small Danish samples (Table 9.6). The excessive wear in the Mesolithic dentitions resulted in alveolar abscesses that are still visible but not in tooth loss, because the affected persons did not extract the involved teeth despite the fact that they often suffered from toothache. The antemortem tooth loss differed in the two Scanian samples from Skateholm because of different age compositions in the samples.

A few individuals suffered from periodontal disease and extensive tooth loss beginning early in adulthood. Progressive periodontal disease was observed in one female from the Vedbæk group, and one individual from the Early Neolithic had a toothless lower jaw. Toothless individuals became more common

Table 9.6. Frequency of Antemortem Tooth Loss

	Individuals		Teeth	
	Aff./Obs.	%	Aff./Obs.	%
Denmark				
Mesolithic				
Vedbæk	1/14		1/380	
Other sites	0/17		0/479	
Sweden				
Late Mesolithic				
Skateholm II	4/42	9.5	17/855	2.0
Skateholm I	1/469	0.2	1/16	6.3
Denmark				
Early Neolithic	6/25	24.0	29/1080	2.7
Middle Neolithic	5/35	14.3	11/539	2.0
Late Neolithic	11/64	17.2	57/1827	3.1
MN/LN[a]	22/162	13.6	89/3237	2.7

Note: Aff. = affected; Obs. = observable; % = percentage; MN = Middle Neolithic; LN = Late Neolithic.

[a] Skulls and jaw fragments included from megalithic graves dating from the Middle and Late Neolithic periods.

in the Late Neolithic period. The accumulation of calculus and its position on the tooth crown and root surfaces indicate that chronic inflammation of the gums sometimes occurred in both the Mesolithic and Neolithic periods.

Paleopathology

Skeletal stress indicators and pathologies may reflect the health status of Mesolithic and Neolithic populations. The shift from a foraging to a farming economy is sometimes thought to have increased the incidence of malnutrition, disease, and dental pathology to such an extent that a marked change accompanied the transition. According to Jackes and colleagues (1997), this pattern is not necessarily similar in all regions, and the hypothesis has yet to be tested in different ecological zones. Most studies have shown that there are few signs of poor health or dietary stress in Mesolithic populations and that rates of pathology during the European Mesolithic are not particularly high when compared to those of the Neolithic populations.

Constandse-Westermann and Newell (1984) studied the influence of pathological changes and stress indicators on the mortality pattern in European Mesolithic populations and found no evidence of higher mortality levels in the Mesolithic compared to the Neolithic. They did not find skeletal evidence of any specific factor that would have contributed substantially to a lower population growth than in the subsequent Neolithic populations. They found a lower

frequency of nutritional and infectious diseases in western European Mesolithic skeletal samples than in Neolithic skeletal samples.

HEALTH CARE

Some skeletons are marked by disease that left the individuals severely disabled for the rest of their lives. In addition, four skulls with possible traces of surgical treatment or healed lesions (interpreted as possible trepanations) show that at least some individuals were cared for in early farming societies and that there was room for the disabled.

VIOLENCE

It is generally believed that traumatic injuries were more frequent in the Mesolithic but that most were not lethal (Bennike 2002). Injuries related to interpersonal violence seem to have occurred mostly in the later phases of the period, when settlements became larger. According to Constandse-Westermann and Newell (1984), the cause of death in only five cases may have been related to direct interpersonal violence in the western European Mesolithic. One is the skeleton of a man who had most likely been shot with an arrow still embedded in his bones. Danish Early Neolithic skulls clearly illustrate that such events were by no means restricted to the Mesolithic (Bennike 1999).

Some Early Neolithic skeletons found in bogs exhibit features strongly indicating that the individuals had not ended their lives there voluntarily. The features are connected to acts of violence—cranial lesions, embedded arrows in bones, and evidence of strangulation (Bennike 1988, 1999). A strikingly high number of Early Neolithic juveniles (16–20 years old) died in bogs. These young people may have been sacrificed in ceremonies or perhaps were executed for breaking social rules (Koch 1998; Bennike 1988).

POROTIC HYPEROSTOSIS

Meiklejohn and colleagues (Meiklejohn and Zvelebil 1991; Meiklejohn 1993; Meiklejohn et al. 1998) have discussed the presence of possible porotic hyperostosis (PH) in some Mesolithic Danish cranial vaults. They argue that it may reflect endemic parasitism, probably attributable to fish tapeworms as a result of eating raw or undercooked fish. Additional causes, such as hypervitaminosis-D and protein poisoning, have been mentioned, probably inspired by Lazenby and McCormack (1975), who pointed to malnutrition related to the problems of high salmon intake on the northwest coast of Canada. The more marine-protein orientation of the diet in Mesolithic Denmark compared to that of the Neolithic (as demonstrated through stable isotope analyses of ^{13}C and ^{15}N) is clear and makes studying the presence of porotic hyperostosis in both periods important.

According to Stuart-MacAdam (1989), the appearance of porotic hyperostosis caused by anemia can vary from slight porotic changes on the surface of the compact bone to very extensive and severe changes that compromise the integrity of the compact bone. The most common localization of porotic hyperostosis is the orbital surface of the frontal bone (termed *cribra orbitalia*). Less often, porotic hyperostosis is seen on the cranial vault, where the central regions of the frontal, parietal, occipital, and sphenoid bones are most often involved. In general, lesions are usually bilateral and symmetrical in both localization and severity (Stuart-MacAdam 1989). The traditionally presumed etiology of porotic hyperostosis of the vault involves nutritional deficiencies, infectious diseases, and parasitism. The condition has usually been thought to represent an anemic response, resulting from hypertrophy of blood-forming tissue within the cranial vault.

In our study, so-called porotic hyperostosis (or, rather, pitting) on the Mesolithic Danish skull surfaces mainly occurs around bregma, at the top of the skull, and along the sagittal suture, often in rather thick-walled skulls. In some cases, the pitting is seen on the surface close to healed lesions in various locations; only very seldom does it occur in the traditional central areas of the vault. Fractured skulls and X-rays allow us to study the external layer of the vault, which always seems to be dense and intact. Apart from the cases of pitting in relation to bone-tissue reaction during healing or infection, pitted areas are most often seen in a triangular area of the top of the mid frontal bone with the apex close to bregma, along the sagittal suture, and at lambda. This triangular area is where the last bone growth of the skull takes place. Therefore, our opinion is that the pitting appearance is probably related to factors such as infection or growth and to skull thickness, rather than to anemia. The triangular area of the frontal bone often appears elevated and corresponds exactly to the area of the frontal bone that is uncovered by the frontal muscles. Meiklejohn and colleagues (1992) noted that porotic hyperostosis is often seen in artificially deformed crania such as those from the proto-Neolithic and Neolithic Near East (four sites, dated to 10,000–6000 BP), and many other researchers have suggested that bandaging may predispose the skull vault to porotic hyperostosis in the uncovered area.

Recently, microscopic studies of the bone tissue of the orbits have demonstrated that cribra orbitalia seems to have many causes other than anemia (Wapler et al. 2004). The same may be true for porotic hyperostosis of the vault, as growth (vascularization), mechanical load (artificial deformation), and infectious conditions (traumatic lesions) cannot be ruled out as being more plausible than parasitism. This theory is supported by the fact that pitting is also seen in Neolithic skulls (often with a particular thickness), whereas the appearance of cribra orbitalia is almost nonexistent in any of the Meso-

lithic/Early Neolithic skulls. We believe that the pitting reflects processes of high vascularization attributable to growth or stress rather than hyperproduction of red blood cells by the diploe.

Conclusion

Biological changes in skeletal material from Denmark and southern Sweden during the Mesolithic-Neolithic transition have been explained in various ways. One is that the observed morphological changes can be the result of a mixture between the autochthonous robust population and more gracile newcomers, leading to a marked change in the genetic composition. Another is that the changes indicate adaptation to a new lifestyle in the indigenous population.

As a result of a long period of contact and cultural diffusion in the Baltic area (lasting almost a thousand years) between the Ertebølle Culture and the Funnel Beaker Culture, stock raising and cereal cultivation in Denmark/Scania happened in a context of broad-scale cultural continuity, according to archaeological analysis (Fischer 2002). Some immigration of farmers from northern Germany or Poland probably occurred circa 5950 BP and in the following centuries (Fischer 2002; Rowley-Conwy 2004).

The Late Mesolithic Danish skulls were similar in morphology to contemporary North European samples (Petersen 1992). The Early Neolithic Danish skulls as a group differed from the Mesolithic skulls as well as from the Late Neolithic skulls. They came from long barrows, megalithic graves, and not least from bogs as part of the wetland votive deposition of goods and human beings that reached a climax by the end of the Early Neolithic and the beginning of the Middle Neolithic (Koch 1998).

With a shift in subsistence from hunter/gatherer to a combination of agriculture and animal husbandry, a corresponding shift in certain key factors related to the production system are to be expected (Schepartz 1989), including changes in mobility, population density, pollution, infectious diseases, nutritional stress, and physical stress.

There is no clear indication of a food crisis in the Danish-Scandinavian skeletal material prior to adoption of the Neolithic Funnel Beaker Culture. The introduction of animal husbandry and cultivation is just one aspect of a long-term process of socioeconomic transformation (Fischer 2002). Nevertheless, the marked morphological changes during the relatively short Early Neolithic period could be evidence of various cultural and subsistence-related stressors acting on the indigenous population for some time before the growing population became well adapted to the new socioeconomic system during the Middle and Late Neolithic periods.

10

The Impact of Economic Intensification and Social Complexity on Human Health in Britain from 6000 BP (Neolithic) and the Introduction of Farming to the Mid-Nineteenth Century AD

CHARLOTTE ROBERTS AND MARGARET COX

This chapter focuses on changes in health during the period of intensification of agriculture and developing social complexity in England from the introduction of farming to the mid-nineteenth century. (There are essentially very few Mesolithic preagricultural skeletal remains in the United Kingdom.) During this time, there were many periods of economic intensification, as societies became more complex and urban centers developed and became industrialized. We wish to test the hypothesis that these changes resulted in deteriorating health. Table 10.1 lists the periods and dates involved.

Prehistory

THE NEOLITHIC

The Neolithic period involved reliance on agriculture, increasing population density, sedentism, large monuments, complex and hierarchical social organization, and some form of territoriality.

Farming was introduced into a forested landscape (Smith et al. 1981: 125). Grazing, crops, and fuel needs led to the gradual disappearance of woodlands. In the later Neolithic, people concentrated on better soils, and there was some regeneration of forest (Parker Pearson 1993: 66). Domestic pigs, cattle, sheep, goats, wheat, barley, linseed, and pulses (Smith et al. 1981: 187–88) were supplemented by wild foods such as acorns, blackberries, sloes, hazelnuts, and crab apples.

THE BRONZE AGE

Bronze and copper artifacts indicate the first metalworking, accompanied by pottery and textile production, and stone working. Intensification of agricul-

Table 10.1. Date Ranges for the Periods under Consideration

Period	Date Range
Neolithic	6000–4500 BP
Bronze Age	4500–2800 BP
Iron Age	2800 BP–first century AD
Roman	AD 43–410
Early Medieval	ca. AD 410–1050
Late Medieval	ca. AD 1050–1550
Post-Medieval	ca. AD 1550–1850

Sources: For the Neolithic, see Whittle 1999; for the Bronze Age, see Parker Pearson 1999 and Champion 1999; for the Iron Age, see Haselgrove 1999.

ture was associated with the emergence of chiefdoms. Trade with the continent is evident in the material culture, and by 3600 BP, connections to central Europe and northern France had become strong (Darvill 1987).

Mining, smelting, and subsequent metalworking required wood and charcoal as fuel; in addition, metal tools accelerated clearance of land, a process that pollen profiles indicate was well under way by 4000 BP (Darvill 1987). Clearing probably resulted in soil erosion and reduced soil fertility. In the mid–Bronze Age, partitioning of land is apparent, and defensive ditches surrounded larger settlements (Darvill 1987). Bronze Age domesticates include the same animals as those of the Neolithic, plus the dog (Parker Pearson 1993, 1999). Crops consisted of wheat, barley, flax, and the pulses. Oats—high in protein and well adapted to colder, wetter, and cloudier climates—were introduced.

THE IRON AGE

The Iron Age is characterized by new technologies including iron working and the rotary quern, new industries, increased manufacture, and wide-ranging exchange of goods (Haselgrove 1999). People moved into lowland areas, increasing the competition for land. In the late Iron Age, however, agriculture expanded into areas not previously worked. Intensive agriculture and the demand for industrial fuel resulted in further forest clearance. Domesticates included cattle, sheep, pigs, goats, horses, dogs, and fowl. Wild animals are rarely seen in the faunal record (Maltby 1996). Barley, wheat, oats, beans, peas, brassicas, flax, and wild plants suggest a mixed and varied economy.

The Historic Period

THE ROMAN PERIOD

The Roman invasion in AD 43 had an enormous impact on the landscape through the clearance of forest, associated with the need for fuel for industries

such as pottery and tile making and smelting. In addition, an intensification of agriculture was required to feed an army and a large civilian population. A new road system opened up previously inaccessible areas of fertile land and facilitated travel and trade (Jones 1996).

Although most of the population was rural, the Romans brought urbanism to Britain. Twenty major and seventy minor towns were built (Wacher 2000: 56). Towns provided centers for trade of agricultural produce, and they also developed a degree of sanitation infrastructure, including a water supply, drainage systems, latrines, and bathing facilities. They also tended to accumulate refuse, vermin, and disease.

Improvement in tools to clear land and manuring of the land promoted intensive agriculture. Crops included wheat, barley, rye, oats, flax, beans, rape, peas, turnip, carrots, parsnips, cabbages, broad beans, celery, fruit trees and shrubs, and vines. The major domesticated animals as per the preceding Iron Age also included fowl, but wild boar, deer, wild geese, and fish and shellfish provided a varied diet.

THE EARLY MEDIEVAL PERIOD

By AD 410, Roman control over Britain had ended. The urban function of many small towns disappeared, and settlement became more rural, resulting in economic decline and political instability (Jones 1996: 239). Immigration of people from the continent is evident.

At the end of the sixth century, Christianity was adopted, churches were built, monasteries were established, and urban centers with developed trade networks had emerged (Dark 2000: 130). In the seventh century, intensified food production filled the needs of developing urban centers (Arnold 1997: 37). In the south of England, trading ports became common. Most people had a balanced diet, including meat, fish, eggs, cheese, butter, ale, wine, and a range of vegetables and fruit. However, in AD 664, the writer Bede noted that there were unspecified hunger-related problems, as occurred in later centuries of this period.

By the tenth century, England was divided into shires, each with its own fortified towns, or *buhrs,* which acted as centers of industry and as collecting points for a range of goods, including agricultural produce from rural areas. By 1066, Medieval kingdoms in Britain had come to involve complex systems of government (Hills 1999: 192). Domesticated sheep, goats, cattle, pigs, and fowl are evident, as are wild species. Wheat, barley, rye, oats, beans, peas, flax, and hemp were grown (Vince 1989). In the Domesday survey of 1086, only 10 percent of the population lived in towns (Welch 1992: 120).

THE LATE MEDIEVAL PERIOD

In the Late Medieval period, the population of England doubled (Dyer 1989); climate and landscape changed; and trade increased. The AD 1066 "Conquest" brought political stability. The warmest weather of the millennium occurred between AD 1000 and 1300 (Lamb 1995), aiding agriculture and supporting a larger population. However, climate-related decline in agricultural productivity produced famines in the early fourteenth century, exacerbating the impact of the Black Death and significantly depopulating both rural and urban areas. The populations of some towns declined by 35–50 percent. Population numbers did not recover until after AD 1470 (Dyer 1989: 140).

A productive countryside promoted increased craft specialization, trade, and industry, creating a consumer-led monetary economy. Urbanization brought pollution of air and water related to problems of waste disposal, sewage, burning of wood and coal, and crafts and industries such as metalworking, tanning, and cloth and leather making. Some industrial processes increased risks of occupational accidents such as burns and fractures.

Changes in diet reflected growth in towns and markets and increasing overseas trade but also social stratification. Bread, porridge, and ale provided the diet of the lower social classes; meat and fish supplemented the diets of the wealthy. The poorest peasant might only have had vegetables and water. Barley and oats, with pulses, vegetables, and fruit were generally available, as were wild fruits, nuts, and berries in season. Sheep, pigs, chicken, geese, wild game, and fish were consumed according to social status. Sugar appeared in the thirteenth century, although its expense limited its use, but honey was used as a sweetener and for making mead by the poorer majority of the population.

THE POST-MEDIEVAL PERIOD

From this period forward, historic documents including parish records, registers, census returns, and death certificates such as the London Bills of Mortality supplant archaeology as the main source of information.

For most in this period, diet was adequate, and living conditions and industrial activity were as before. Population growth accompanied urbanization, industrialization, commercialization of agriculture, and improvement of crops, livestock, and technology (Whyte 1999). Agricultural productivity was helped by enclosures of land and the working of newly drained marginal land, allowing new settlements to develop. However, there were severe harvest failures at times, leading to famine and epidemic disease. Diet for the poor remained unchanged, but improvements in transport meant that produce was distributed regionally and was probably fresher. By the end of the period, the poor had come to subsist on potatoes and imports of (now much cheaper) sugar and

tea. The eighteenth century saw improved meats and availability of dairy foods year-round. New fodder crops allowed animals to be overwintered, producing a shift to farmed, rather than wild, meat. In the mid-nineteenth century, extreme hardship hit the poor. Enclosure meant that the rural poor could not be self-sufficient but became vulnerable to harvest failures, price increases, and food shortages. Cash cropping (a high-risk subsistence strategy) replaced subsistence farming. However, for the wealthy, food variety and quality improved in towns and cities.

By the end of the period, as a result of urban immigration, half the population lived in urban areas (Whyte 1999; Scott and Duncan 1998). Transformation of Medieval roads, construction and commercialization of canal systems, and growth of ports and rivers allowed better distribution of goods (and people). But higher urban populations created problems of water supply and waste disposal, in addition to appalling working conditions and housing. Air pollution involving smoke from coal fires and industrial toxins were increasingly a problem.

Summary

Beginning with the introduction of agriculture in the Neolithic in Britain, there was an increase in social complexity through time, and continuing into the Late and Post-Medieval periods, with a lull in the Early Medieval period. Rural existence was the rule until the late Iron Age. Urbanism developed more fully in the late Roman period, was abandoned in the Early Medieval (EM) period, then was reinstated, maintained, and intensified through the remainder of the sequence. The environmental and archaeological records indicate periods of intensification of agriculture in the late Bronze Age, the Late Iron Age, the Roman period, the seventh century AD, the Late Medieval (LM) period (late eleventh–early fourteenth centuries), and the Post-Medieval (PM) period. The question is whether skeletal evidence reflects these social and economic changes.

Materials and Methods

We utilized skeletal data from nearly three hundred published and unpublished skeletal reports, much of the work done by us (Roberts and Cox 2003). There are relatively few prehistoric skeletal remains in Britain, but most reported sites provided some data. For the Roman period onward, we used data only from sites with more than fifty individuals, or smaller samples if well preserved. Standards for recording have recently improved (Buikstra and Ubelaker 1994; Brickley and McKinley 2004). However, many reports cited in

Table 10.2. Number of Individuals and Sites for Each Period

Period	Individuals	Sites
Neolithic	772	24
Bronze Age	291	45
Iron Age	591	21
Roman	5,716	52
Early Medieval	7,122	72
Late Medieval	16,327	63
Post-Medieval	3,790	15

Table 10.3. Stature through Time

	Male			**Female**			Number
Period	Mean	Range	*N*	Mean	Range	*N*	of Sites
Mesolithic	165	160–168	3	157	152–162	2	1
Neolithic	165	162–177	71	157	151–161	36	17
Bronze Age	172	167–177	61	161	154–164	20	36
Iron Age	168	164–174	113	162	154–164	72	15
Roman	169	159–178	1,296	159	150–168	1,042	52
E. Medieval	172	170–182	996	161	152–170	751	62
L. Medieval	171	167–174	8,494	159	154–165	7,929	63
P.-Medieval	171	168–174	558	160	156–164	540	11

Note: Stature is measured in centimeters. *N* = number of individuals on which mean is based; E. Medieval = Early Medieval; L. Medieval = Late Medieval; P.-Medieval = Post-Medieval.

Roberts and Cox (2003), published both before and after 1994, do not follow the new standards. We were dealing with sets of data of varying utility. The available data vary considerably between geographic regions and time periods. Most work on skeletal samples in Britain comes from England. The number of individuals considered is shown in Table 10.2. Health indicators evaluated include stature, dental caries, enamel hypoplasia, infectious disease, anemia, and other data as appropriate.

Results

STATURE

Stature data exist for all periods under consideration (Table 10.3; Figure 10.1). The stature of Mesolithic populations provides a base from which to view later periods. Neolithic mean stature for both sexes remained the same, when compared to the Mesolithic. Mean Bronze Age stature for men and women both rise, but Iron Age stature decreases for males and rises for females. Stature of Roman males increases, while that of females declines.

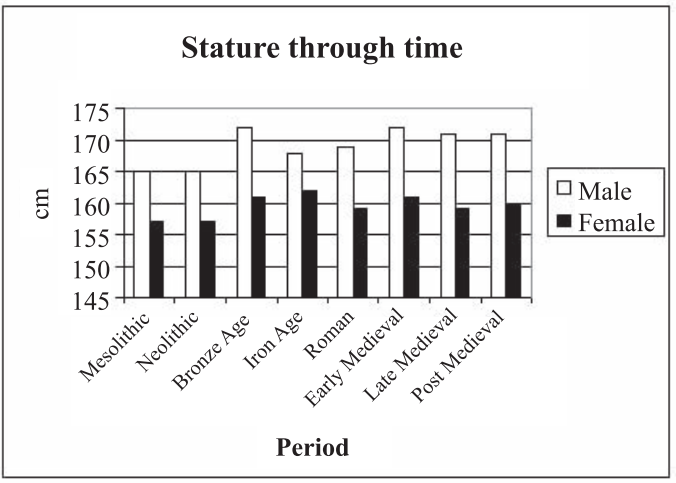

Figure 10.1. Trends in stature through time in English populations.

In the EM period, men and women increase in height, in the LM period, male and female mean statures decline, and statures remain the same for males but rise for females in the PM period.

DENTAL HEALTH

Table 10.4 and Figure 10.2 display frequencies for dental disease through time. (Individual frequencies for the Late and Post-Medieval periods were not available.) The frequency of individuals with dental disease increases from the Neolithic to the Bronze Age, declines in the Iron Age, increases again in the Roman period, and declines in the EM era. Dental caries (whether per tooth or per individual) mirror that pattern (Table 10.5; Figure 10.2), with the addition of a

Table 10.4. Frequency of Dental Disease through Time

	Individuals	
Period	Aff./Obs.	%
Neolithic	14/772	1.8
Bronze Age	82/291	28.2
Iron Age	44/591	7.4
Roman	646/5,716	11.3
E. Medieval	311/7,122	4.4
L. Medieval	—	—
P.-Medieval	—	—

Note: Aff. = number of individuals affected; Obs. = number of individuals observable; % = percentage; E. Medieval = Early Medieval; L. Medieval = Late Medieval; P.-Medieval = Post-Medieval.

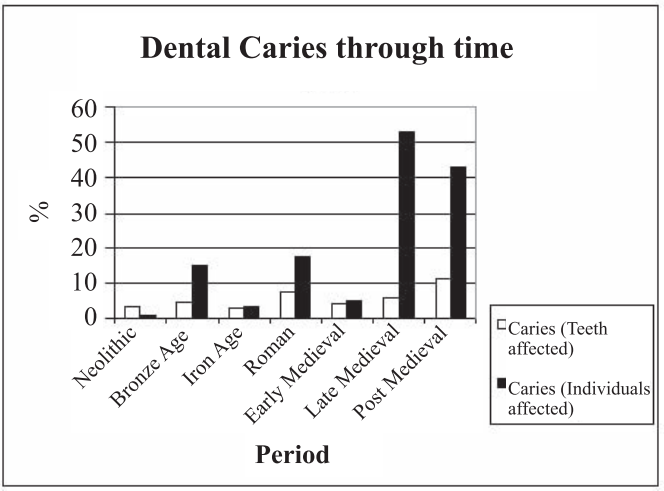

Figure 10.2. Trends in dental caries through time in English populations.

rise in the number of caries per tooth and individuals affected for the Late and Post-Medieval periods.

The frequency of linear enamel hypoplasia mirrors the trend seen for dental caries until the EM period, when hypoplasia increases per individual but declines per tooth (Table 10.6; Figure 10.3). Enamel defects increase again in the LM period but decline in the PM era, the latter probably reflecting small sample sizes.

ANEMIA

Table 10.7 and Figure 10.3 show the frequency of cribra orbitalia per individual. Anemia rates mirror those of dental disease, although a slight decline occurs in the PM period.

Table 10.5. Frequency of Caries through Time

	Teeth		Individuals	
Period	Aff./Obs.	%	Aff./Obs.	%
Neolithic	73/2,208	3.3	5/772	0.7
Bronze Age	35/730	4.8	44/291	15.1
Iron Age	240/8,232	2.9	19/591	3.2
Roman	2,179/29,247	7.5	1,010/5,716	17.7
E. Medieval	1,636/38,911	4.2	375/7,122	5.2
L. Medieval	1,980/35,665	5.6	1,376/2,614[a]	53.0[a]
P.-Medieval	1,451/12,933	11.2	366/850[a]	43.1[a]

Note: Aff. = number of individuals affected; Obs. = number of individuals observable; % = percentage; E. Medieval = Early Medieval; L. Medieval = Late Medieval; P.-Medieval = Post-Medieval.

[a] Individuals with dentitions.

Table 10.6. Frequency of Linear Enamel Hypoplasia through Time

	Individuals		Teeth	
Period	Aff./Obs.	%	Aff./Obs.	%
Neolithic	5/772	0.6	—	—
Bronze Age	122/291	41.9	—	—
Iron Age	12/591	2.0	—	—
Roman	380/5716	6.6	437/4796	9.1
E. Medieval	640/7122	9.0	384/5167	7.4
L. Medieval	628/1775[a]	35.4[a]	—	—
P.-Medieval	3/528[a]	0.6[a]	—	—

Note: Aff. = number of individuals affected; Obs. = number of individuals observable; % = percentage; E. Medieval = Early Medieval; L. Medieval = Late Medieval; P.-Medieval = Post-Medieval.
[a]Individuals with dentitions.

Table 10.7. Frequency of Cribra Orbitalia through Time

	Individuals		Sites
Period	Aff./Obs.	%	*N*
Neolithic	18/772	2.3	3
Bronze Age	17/291	5.8	8
Iron Age	32/591	5.4	7
Roman	460/5,716	8.0	30
E. Medieval	404/7,122	5.7	45
L. Medieval	640/5,752	11.1	33
P.-Medieval	238/2,660	8.9	7

Note: Aff. = number of individuals affected; Obs. = number of individuals observable; *N* = number of sites; % = percentage; E. Medieval = Early Medieval; L. Medieval = Late Medieval; P.-Medieval = Post-Medieval.

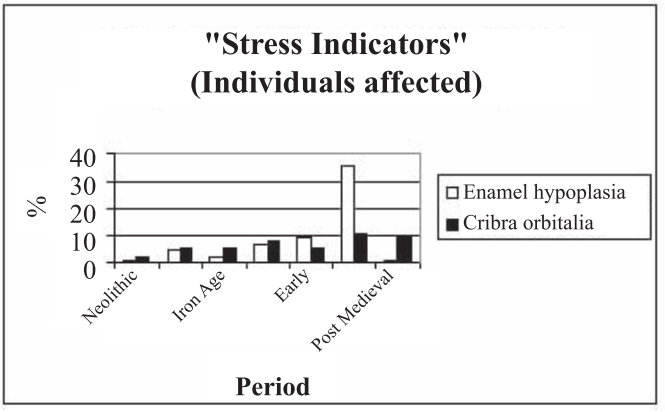

Figure 10.3. Percentage of individuals affected by "stress indicators" in English populations.

Table 10.8. Frequency of Infectious Disease through Time

			Disease			
Period	Ribs	M-Sinus.	Leprosy	TB	Trep.	Nonspecific
Neolithic *N*	1/772	2/772	0/772	0/772	0/772	18/772
Neolithic %	(0.1)	(0.3)	(0.0)	(0.0)	(0.0)	(2.3)
Bronze Age *N*	1/291	2/291	0/291	0/291	0/291	8/291
Bronze Age %	(0.3)	(0.7)	(0.0)	(0.0)	(0.0)	(2.7)
Iron Age *N*	1/591	0/591	0/591	1/591	0/591	9/591
Iron Age %	(0.2)	(0.0)	(0.0)	(0.2)	(0.0)	(1.5)
Roman *N*	45/5716	36/5716	2/5716	11/5716	0/5716	381/5716
Roman %	(0.8)	(0.6)	(0.03)	(0.2)	(0.0)	(6.7)
E. Medieval *N*	33/7122	93/7122	18/7122	18/7122	0/7122	460/7122
E. Medieval %	(0.5)	(1.3)	(0.3)	(0.3)	(0.0)	(6.5)
L. Medieval *N*	—	276/2076	108/16327	48/16237	14/16237	330/6652
L. Medieval %	—	(13.3)	(0.7)	(0.3)	(0.1)	(5.0)
P.-Medieval *N*	—	74/1075	1/3790	8/3790	17/2198	75/1371
P.-Medieval %	—	(6.9)	(0.03)	(0.2)	(0.8)	(5.5)

Note: *N* = number of individuals affected / number of observable individuals; % = percentage affected; E. Medieval = Early Medieval; L. Medieval = Late Medieval; P.-Medieval = Post-Medieval; m-sinus = maxillary sinusitis; TB = tuberculosis; Trep = Treponemal disease.

INFECTIOUS DISEASE

Table 10.8 shows the frequencies of infectious diseases per individual. Nonspecific infections appear to have been infrequent overall, but rates rise from the Neolithic to the Bronze Age, from the Iron Age to the Roman period, and from the Early Medieval to the Late and Post-Medieval periods. Leprosy did not appear until the Roman period (fourth century AD). Its frequency increases in the

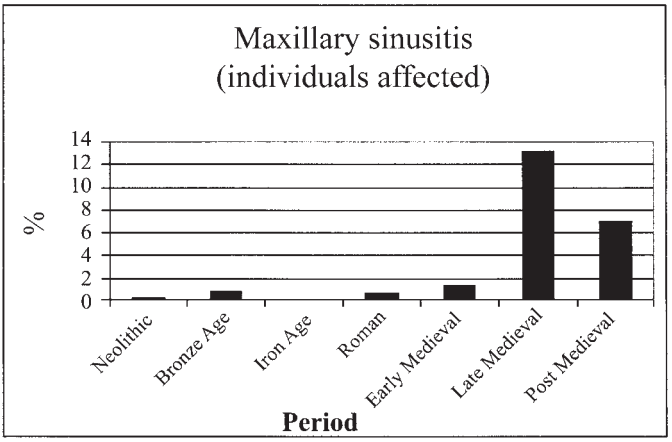

Figure 10.4. Percentage of individuals affected by maxillary sinusitis in English populations.

Table 10.9. Joint Disease and Spondylolysis from the Neolithic to Early Medieval Period

	Percentage of Individuals Affected				
Period	Neolithic	Bronze Age	Iron Age	Roman	Early Medieval
JD	10.2	16.8	5.3	14.4	8.8
SJD	7.0	11.0	23.2	7.1	6.1
ESJD	1.8	6.9	4.6	8.5	4.5
SN	1.3	4.4	1.0	4.8	2.9
Spondylolysis	0	1.4	0.7	0.9	1.3

Note: JD = individual joints affected; SJD = spinal joint disease; ESJD = extra spinal joint disease; SN = Schmorl's nodes.

EM and LM periods, but there is only one PM case. Tuberculosis (again, only one case) occurred first in the Iron Age and remained relatively stable through time; readers are however referred to Roberts and Buikstra (2003) for detailed discussion of frequencies in England. Treponemal disease did not appear until the LM period. Maxillary sinusitis was present (Figure 10.4) but not common from the Neolithic to the Roman period, and its frequency increases in the LM period but declines unexpectedly in the PM period, probably reflecting small samples.

OTHER HEALTH INDICATORS

Joint disease and spondylolysis occurred from the Neolithic through the Early Medieval period (Table 10.9). Generally speaking, the frequency of these problems increased from the Neolithic to the Bronze Age, declined in the Iron Age, and increased from the Roman to EM period. However, the frequency of joint disease declined in EM period while spondylolysis increased.

Tumors and congenital diseases appeared in the Neolithic, as did osteoporosis (although this was rare) and possibly diffuse idiopathic skeletal hyperostosis (DISH). In the Bronze Age, new tumors and spina bifida occulta first occurred. In the Iron Age, weapon injuries increased, and new tumors and congenital diseases are evident, and the earliest-noted specific infection (tuberculosis) is seen. In the Roman period, there appears to have been a wider variety of pathological conditions, including rickets and scurvy; another new infection, leprosy; and new joint diseases such as gout, ankylosing spondylitis, and rheumatoid and psoriatic arthritis. DISH became more common. In the EM period, new tumors and Paget's disease were present.

For the LM period, documentary evidence tells us that new diseases such as the plague (all not necessarily affecting the skeleton) were present. Treponemal disease occurred. Paget's disease and DISH became more common. Rickets and new congenital conditions and tumors appeared. For the PM period,

documentary evidence tells us that many of the soft-tissue diseases that do not affect the skeleton (smallpox, plague, measles, whooping cough, scarlet fever, diphtheria, cholera, typhoid, and typhus) became prevalent.

Discussion

Trends in the data suggest a decline in health over time as social complexity developed and agriculture intensified. Neolithic and Bronze and Iron Age populations have relatively low frequencies of disease, possibly reflecting their small populations. The Early Medieval era, also characterized by a largely rural population, appears to have been relatively healthy, but the conditions of the Late Medieval and Post-Medieval periods were conducive to deteriorating health.

STATURE

Stature increased through time for males, peaking in the Bronze Age and declining in the Late Medieval period. No peak in female stature during the Bronze Age is apparent. Stature during the Early Medieval period was higher than in previous and subsequent periods, reflecting the effect of immigration of taller people and/or a healthier rural-based life. Steckel (1995) argues that heights accurately reflect health status. The general rise in stature in Britain through time, despite increased social complexity and agricultural intensification, may reflect the ability of the population to adapt to changing circumstances, as well as to dietary and disease stress.

DENTAL DISEASE

The number of teeth affected by caries was generally low through prehistory, although a peak occurs in the Bronze Age and again in Romano-British populations (Roberts and Cox 2003). Dental caries rates decline in the Early Medieval period, possibly reflecting the more rural economy and limited access to sucrose, although honey and fruits were evidently consumed. In the Late Medieval and Post-Medieval periods, caries rates increase (per tooth or per individual). At some sites, the number of individuals affected was very high.

INDICATORS OF STRESS

The prevalence of cribra orbitalia generally increases in frequency through time, probably reflecting an increased pathogen load related to the importance of agriculture and to the establishment of settled communities, allowing infectious disease to increase. In Britain there is no clear evidence that populations through time lacked access to dietary iron-containing foods (except perhaps the very poor in the Late and Post-Medieval periods), so cribra orbitalia was

probably the result of increased pathogen load. Its frequency does not vary much in time until the Late Medieval and Post-Medieval periods, when urban poverty encouraged infection.

Linear enamel hypoplasia gradually increased through time from very low levels of individuals affected, with a decline in the Iron Age. LEH increased to very high levels in the Late Medieval period (when one-third of people had LEH), but this is followed, surprisingly, by a fall in rates in the Post-Medieval period. The data suggest that people in Britain were stressed but not greatly until the Late Medieval period, indicating that their disease levels were not particularly high during growth and/or that their nutritional requirements were met. In the Late Medieval period, we do have evidence for agricultural intensification, high population numbers, poor housing and sanitation, polluted water supplies, famines, and epidemic diseases such as the plague—all probably contributing to the high levels of enamel hypoplasia observed. Of course, that these observations are made on adults reflects the fact that they overcame the stress during growth and did not die, suggesting that they were healthy survivors.

NONSPECIFIC INFECTION: PERIOSTITIS, OSTEITIS, AND OSTEOMYELITIS

Nonspecific infection occurred in all time periods but became significant only in the Roman period, when rates per individual are the highest of all the periods, despite attention to hygiene, safe water, waste disposal, and bathing. Large numbers of people living in close proximity to each other and their animals appear to have cancelled out those benefits.

There is a slight decline in frequency of infection in the Early Medieval period and a further decrease in the Late Medieval era. As is typical of people in a rural environment, Early Medieval populations may have put themselves at risk through their agricultural work, but the higher frequency of nonspecific infection in the Early Medieval period when compared to the Late Medieval period is puzzling. The trend may indicate that the latter population was actually less healthy, with more people dying without signs of infectious disease on their skeletons. One other explanation may be that the Black Death, not visible in skeletons, was a major killer in the fourteenth through nineteenth centuries, which possibly affect the data. Post-Medieval rates of non-specific infection are also lower than those of the Early Medieval and Roman periods but higher than the those of the Late Medieval era.

NONSPECIFIC INFECTION: MAXILLARY SINUSITIS

Frequencies of maxillary sinusitis are low until the Early Medieval period, concomitant with a rise in particulate air pollution from burning fuels such as

wood, coal, and dung and from intensification of industries. Historical data indicate that pollution was a problem in large towns and cities in these periods (Brimblecombe 1975, 1978).

SPECIFIC INFECTIONS

Specific infections did not become a problem until the Roman period. Tuberculosis first appeared in the Iron Age, but skeletal indicators remain rare until the Early Medieval and Late Medieval periods (Roberts and Buikstra 2003). Leprosy first appeared in southern England in the Roman period, but it became more prevalent in the Early Medieval period and declined in frequency through the Late Medieval and Post-Medieval periods (Roberts 2002). Historical sources indicate a high frequency of leprosy in England in the Late Medieval period and a decline from the fourteenth century onward, reflecting reduced skeletal involvement in leprosy and/or the increase in tuberculosis, a competing infection (Manchester 1991).

Treponematosis did not appear until the Late Medieval period, during the fifteenth century (Roberts and Cox 2003; Mays et al. 2003). It increased in the Post-Medieval period, probably reflecting increased trade and contact with the continent to the east, rather than being attributable to Christopher Columbus' voyage to the New World, as was once proposed (see Baker and Armelagos 1988 for a summary of theories of treponematosis development).

In summary, the data on infectious disease suggest that infections increased from the Roman period onward, reflecting the development of complex societies and urban environments. Evidence for specific infection is relatively rare compared to nonspecific infection.

OTHER HEALTH INDICATORS

Stress to the joints increased in the Bronze Age and Roman periods, reflecting agriculture, specialized crafts, and industry in the form of mining. Specific work patterns can cause joint disease, but work was probably not the only predisposing factor. A decline in the frequency of joint disease can be seen in the Iron Age and Early Medieval periods. The Iron Age decline may reflect small samples, but the Early Medieval decline could be related to a difference in rural work patterns and reduced stress.

Conclusions

Despite limited data, health appears to have deteriorated through time, although the picture is not consistent for all health indicators, and many health indicators are not apparent in the skeletal record. Wood and colleagues (1992) document the problems of inferring health from the skeleton, particularly in

comparing skeletons with no visible signs of stress (healthy or not?), and those with chronic healed lesions. For the most part, the data described here refer to healed lesions. One could argue that health improved because there is more evidence of chronic long-standing disease through time. However, to contract the disease in the first place, a person has to be living in the right environment and with the right predisposing factors, even if the person's immune system is strong and able to withstand death. Therefore, the British skeletal data do indeed suggest a decline in health through time.

11

What Can Pathology Say about the Mesolithic and Late Neolithic/Chalcolithic Communities?

The Portuguese Case

EUGÉNIA CUNHA, CLÁUDIA UMBELINO, ANA MARIA SILVA, AND FRANCISCA CARDOSO

Portugal is rich in human skeletal remains from both the Late Mesolithic and the Late Neolithic/Chalcolithic. The absence of series from the Early Neolithic prevents the analysis of the effects of the initial adoption of farming on human health. But with large samples of both Mesolithic skeletons dating between 7500 BP and 5500 BP, and Late Neolithic/Chalcolithic skeletons from approximately three thousand years later, we can evaluate the medium- to long-term effects of the transition.

More than three hundred skeletons coming from both the Muge and the Sado shell middens permit study of the daily life of Late Mesolithic semisedentary hunter-gatherers in Europe. Over one thousand individuals are available from the Late Neolithic/Chalcolithic farmers.

We are concerned with comparative analysis of infection, dental wear, caries rates, and diet. Is it true, as expected, that the last nomads experienced more traumatic injuries? Did Neolithic economies and populations lead to an increase of infectious processes? Do dental wear patterns and dental caries rates reflect the transition to agriculture? Despite questions about sample sizes and preservation, which affect all conclusions reported here, our preliminary results shed light on these questions. Upon completion of the detailed database that is under construction, we expect to provide more-definite conclusions.

Mesolithic Sites

The Mesolithic sample, totalling at least 309 individuals (ranging from whole skeletons to individual bones), comes from the Muge and Sado shell middens, providing samples of 197 and 112 individuals, respectively. The Muge sample includes only about 65 percent of the total skeletal population from the site.

Meiklejohn and colleagues (1984) have suggested that in general, Mesolithic economies saw the appearance of semipermanent settlements and an increase in the density of more evenly spaced sites. This seems to have happened with both the Muge and Sado communities.

The skeletons from both Muge and Sado shell middens are found within deposits of occupation debris, usually as primary individual interments (Jackes et al. 1997). Muge and Sado shell middens were simultaneously sites of the living and of the dead. The sites functioned as cemeteries and also as semipermanent residences for hunter-gatherer populations residing there for most of the year (Raposo 1994).

MUGE SHELL MIDDENS

Located on the Tagus old terraces, approximately 80 kilometers northeast of Lisbon (Figure 11.1), the Muge shell middens have a long research history (Cunha and Cardoso 2002–3). The osteological series analyzed here come from four sites: Cabeço da Amoreira, Cabeço da Arruda, Moita do Sebastião, and Cova da Onça. The first three sites are located near the Muge River—with Cabeço da Arruda on the right bank and Cabeço da Amoreira and Moita do Sebastião on the left—while Cova da Onça is found near the Magos River. The

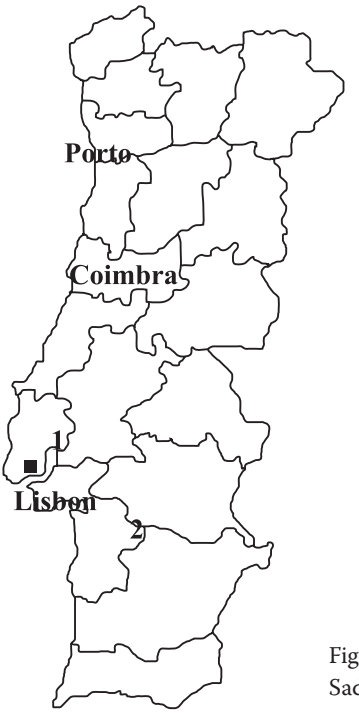

Figure 11.1. Map of Portugal with Muge (1) and Sado (2) shell midden locations.

Table 11.1. Minimum Number of Individuals for Muge Shell Middens

Shell midden name	No. of individuals
Cabeço da Amoreira	21
Cabeço da Arruda	63
Moita do Sebastião	51
Cova da Onça	32
Material with unknown specific provenance, Coimbra	5
Material with unknown specific provenance, Oporto	25
Total	197

Table 11.2. Minimum Number of Individuals for Sado Shell Middens

Site	No. of individuals
Arapouco	32
Cabeço das Amoreiras	6
Vale de Romeiras	26
Cabeço do Pez	32
Poças de S. Bento	15
Várzea da Mó	1
Total	112

largest of all was probably Moita do Sebastião (now destroyed) at approximately 90–100 meters long, 75 meters wide, and 2.5 meters high. The other two main shell middens, Cabeço da Arruda and Cabeço da Amoreira, were slightly smaller (Cunha and Cardoso 2001). Sample sizes are reported in Table 11.1.

Many radiocarbon dates exist for the sites (Lubell et al. 1986, 1994; Cunha and Cardoso 2002–3; Cunha et al. 2003 [the latter two works contain the dates obtained by our team]). All of the four sites under examination were settled at about 7000 BP and lasted at least one thousand years.

SADO SHELL MIDDENS

The Sado shell middens, which are less well known because they have attracted less attention, are located on the lower course of the Sado River, some one hundred kilometers south from Muge. Eleven sites were reported (Arnaud 1989), six of which have yielded human skeletal remains (Table 11.2) (Cunha and Umbelino 1995–97; Cunha et al. 2003). Several radiocarbon dates (Cunha et al. 2003) confirm their contemporaneity with the Muge shell middens. The results of archaeological investigations of the Sado sites, providing a sample of around one hundred skeletons, remained unpublished until 1997 (Cunha and Umbelino 1995–97).

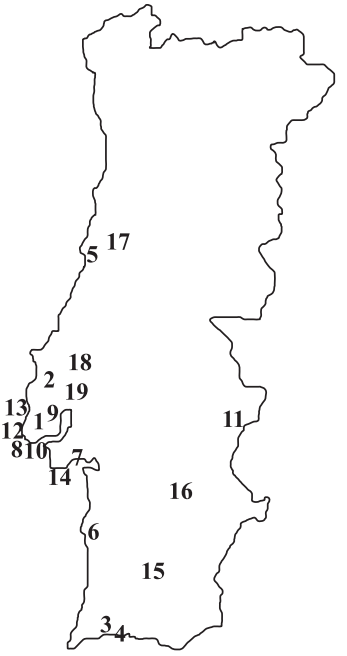

Figure 11.2. Map with locations of some Portuguese Neolithic and Chalcolithic osteological samples, indicated by numbers: *1*, Dolmens region of Belas (Sintra); *2*, Natural caves of Cesareda (as Casa da Moura); *3*, Monument of Aljezur; *4*, Necropolis of Alcalar; *5*, Dolmens of region of Figueira da Foz; *6*, caves of Melides; *7*, Hipogeus of Casal do Pardo (Palmela); *8*, Hipogeus of Alapraia (Cascais); *9*, Hipogeus of Tojal de Vila Chã (Carenque); *10*, Hipogeus of São Pedro do Estoril; *11*, Monuments of region of Elvas; *12*, Praia das Maçãs; *13*, Praia da Samarra; *14*, Natural caves of region of Sesimbra (Lapa do Fumo; Lapa da Furada, Lapa do Bugio); *15*, Monument of Herdade da Malha Ferro; *16*, Escoural (cave); *17*, Natural caves of Eira Pedrinha; *18*, Natural cave of Lugar do Canto (Valverde, Alcanede); *19*, Algar do Bom Santo.
Adapted from Silva 2002: 36.

According to the radiocarbon dates obtained for our project (Cunha et al. 2003; Cunha and Cardoso 2002–3), Arapouco seems to be the oldest site (7200 ± 130 BP), immediately followed by Cabeço das Amoreiras. The dates obtained for Cabeço do Pez (6740 ± 110 BP) suggest a slightly later occupation (Cunha and Umbelino 2001).

The sites were apparently organized around two main base camps: the larger shell middens at Cabeço do Pez and Poças de São Bento. The remaining sites were smaller seasonal settlements (Arnaud 1989; Araújo 1999).

Late Neolithic/Chalcolithic

Late Neolithic/Chalcolithic human remains are relatively common. They are mainly exhumed from a variety of collective burial places, including dolmens, *tholoi* (vaulted chamber graves), and natural and artificial caves, in addition to some of uncertain typology. In these graves, the bones are commonly found to be very fragmented and disturbed, with almost-total absence of any anatomical articulation (Silva 1996a, 1996b, 2002, 2003b).

We have selected nine different sites that together provided more than

Table 11.3. Radiocarbon Dates for the Analyzed Neolithic/Chalcolithic Sites

Site	BP result (reference no.)	Cal bc 2δ
Cabeço da Arruda I (CAI)	4240 ± 50 BP (Beta-132975)	2915–2680 cal BC
	4370 ± 70 BP (Beta-123363)	3310–2880 cal BC
Cabeço da Arruda II (CAII)	4230 ± 100 BP (UBAR-538)	3090–2495 cal BC
	4700 ± 80 BP (Sac-1613)	3647–3149 cal BC
Cova da Moura (CM)	3950 ± 60 BP (UBAR-536)	2610–2205 cal BC
	4715 ± 50 BP (UBAR-593)	3636–3371 cal BC
Dólmen de Ansião (DEA)	4640 ± 90 BP (Sac-1559)	3637–3094 cal BC
Eira Pedrinha	4480 ± 60 BP (Beta-134363)	3360–2925 cal BC
Paimogo I (PM)	4250 ± 90 BP (Sac-1556)	3077–2581 cal BC
	4130 ± 90 BP (UBAR-539)	2890–2475 cal BC
Monte Canelas I (MCI)	4370 ± 60 BP (OXA-5515)	3290–2880 cal BC
	4420 ± 60 BP (OXA-5514)	3340–2900 cal BC
São Paulo II (SP)	3960 ± 190 BP (UBAR-629)	2905–1950 cal BC
	3870 ± 70 BP (UBAR-630)	2553–2137 cal BC
Serra da Roupa (SR)	4560 ± 110 BP (Sac-1611)	3626–2917 cal BC

one thousand individuals for discussion (Gama and Cunha 2003; Silva 1996a, 2002, 2003b). The majority came from sites along the Atlantic coast (see Figure 11.2). Radiocarbon dates on human bone place these samples around 4715 BP to 3870 BP (Table 11.3) (Silva 1996a, 1996b, 2002, 2003b).

Pathology

There is considerable heterogeneity in the preservation of the Mesolithic skeletal material. Some individuals are represented by a single bone; others are quite complete, including even the small bones of the hands and feet. Many skeletons were excavated in the late nineteenth and early twentieth centuries using methods prevalent at the time. Some skeletons were exhumed in blocks of sediments; some were treated by paraffin (especially at Sado), whereas others remain embedded in a dense calcified matrix. Attempts to remove the paraffin have left further damage on bone surfaces.

Calcite not only covered the bone surface but also filled the medullary cavities of long bones, limiting radiographic analysis. Other important factors include damage by plant roots and macro- and microfauna actions, particularly gnawing, which left distinctive marks on the bone surfaces. In some cases, the sediment over the bones collapsed, leading to a flattened and crushed appearance of skulls and mandibles, in particular.

Not all of these postmortem alterations can easily be distinguished from antemortem lesions. Careful observation, however, usually allows us to distinguish truly pathological cases from the pseudopathology.

Oral Pathologies

MESOLITHIC

The large number of Mesolithic dentitions in occlusion or covered by paraffin or calcite precluded a more extensive study. Therefore, unfortunately the question of interproximal caries, in particular, has not been correctly evaluated. Moreover, severe dental wear disguises the presence of dental caries. In some cases, the root is the only portion left, precluding an assessment of the role of severe dental wear or caries lesion in destroying the tooth. As a result, the frequency of dental caries is clearly underestimated.

Whereas caries prevalence from the total number of observable teeth is around 4.1 percent (67/1624) at Muge, at Sado the figure is 3.9 percent (41/1049) (Cunha et al. 2003). Analysis of dental caries could not be conducted on 13.9 percent (263/1887) of the teeth from Muge and on 10.95 percent (129/1178) of the teeth from Sado (Cunha et al. 2003). Although the frequencies found can be considered quite low, they do not indicate the absence of carbohydrates in the diet, as severe dental caries (see, for example, Figure 11.3) easily demonstrate.

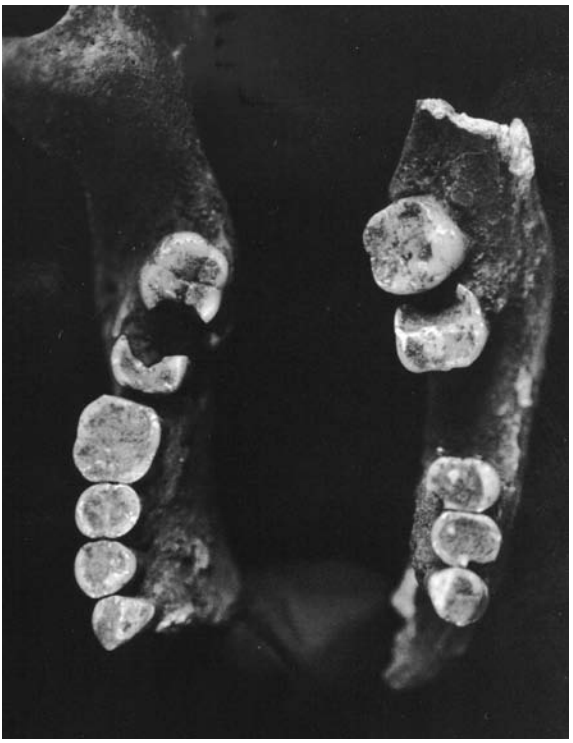

Figure 11.3. Caries lesions in a Mesolithic mandible from the Sado site, Portugal.

Figure 11.4. Severe dental wear in a Mesolithic mandible from the Muge site in Portugal.

Dental wear was evaluated according to Smith's scale (1984: 46). In most of the cases, anterior teeth display a more severe wear than posterior ones. Severe wear on anterior teeth leads us to suppose that the mouth was used for functions other than mastication, including cutting nonfood materials. Severe and angulated dental wear on the anterior dentition may have been caused by the ingestion of bivalves mixed with sand. This could also explain the degree of dental wear found on the posterior dentition (Cunha et al. 2003). Posterior teeth almost always exhibit a flat dental wear. Complete destruction of the cusps, corresponding to maximum grades in Smith's scale (such as the ones shown in Figure 11.4) was not uncommon.

LATE NEOLITHIC/CHALCOLITHIC

The great majority of the Neolithic sites provide only loose teeth. We evaluated the following sites for dental caries: Cabeço da Arruda I and II, Cova da Moura, Dólmen de Ansião, Paimogo I, Monte Canelas I, Eira Pedrinha, São Paulo II and Serra da Roupa (Gama and Cunha 2003; Silva 1996a, 2002). In all, 2,895 permanent teeth were observed. Caries were detected in 8.0 percent of teeth (231/2895; Silva 2002). No differences were found between upper and lower jaws. Furthermore, in general, no statistically significant differences were found among the various sites (Gama and Cunha 2003; Silva 1996a, 2002). However, sites such as Monte Canelas, where cariogenic fruits such as figs and carobs were more widely available, show a higher prevalence of dental caries (Silva 1996a, 1996b).

For dental wear, all types of teeth were considered. The mean value found was 3–4 (out of 8 in Smith's scale) for a total sample of 4,043 teeth. Anterior teeth do not show more severe dental wear than posterior ones. As we are dealing with loose teeth, however, we cannot compare anterior and posterior dental wear for the same individual. Furthermore, the Neolithic individuals do not display distinctive cupped wear on the occlusal surfaces of their molars (Gama and Cunha 2003; Silva 1996a, 2002).

MESOLITHIC VERSUS LATE NEOLITHIC

In around three thousand years, the prevalence of dental caries doubled: from a mean value of 4 percent in the Mesolithic (which may be an underestimation) to almost 8 percent in the Late Neolithic. This difference might reflect a higher consumption of cariogenic foods. Overall there is a decrease in the severity of dental wear from the Mesolithic to the Neolithic/Chalcolithic. The typical pattern of Mesolithic dentitions, in which anterior teeth are more worn than posterior ones, was not observed in Late Neolithic dentitions (see also Lubell et al. 1994).

Our data do not corroborate Smith's (1984) assumption that foragers tend to wear their teeth flat, whereas farmers tend to exhibit a cupped wear. Although Muge and Sado people show a flat pattern, the Late Neolithic people do not present cupped wear. Yet our farmers in general show less severe tooth wear than do foragers. These latter trends were previously noted by Lubell and colleagues (1994).

These differences found between the Mesolithic and Late Neolithic suggest a major dietary transition during the Neolithic in Portugal, a transition that involved a shift in subsistence from foraging and fishing to a more terrestrially focused diet including domesticated animals and plants.

Trauma

MESOLITHIC

In all, fourteen cases in the Muge (n=12) and Sado (n=2) series could be reported as truly traumatic events after pseudopathological lesions, attributable to taphonomic alterations, were excluded. Six of the injuries (43 percent of all Mesolithic lesions) affect the skull and seem to be a consequence of frontal confrontations (Cunha et al. 2004). One injury is a depressed fracture on the frontal bone; it shows clear signs of trephination (Crubézy et al. 2001). Other depressed lesions on adult crania seem to have resulted from blunt impacts. A remaining case from Muge was clearly a dislocation affecting the temporo-

mandibular joint. According to Larsen (1997), such injuries seem to imply the intention of the aggressor to injure rather than kill the targeted victim.

The seven postcranial traumatic events reported here seem to have derived mainly from occupational accidents rather than interpersonal violence. Even the four cases of forearm fractures at Muge, including one involving a subadult (Cunha et al. 2004), may have been caused by falls (Roberts 2000). Besides those, trauma was detected in two metatarsals and one in a fibula.

Only one subadult (at Muge) was affected. Of the thirteen adults with traumas, four seem to be females, seven males. Two affected individuals were of indeterminate sex.

It is generally assumed that traumatic events would occur more frequently in the Mesolithic context, as the result of both interpersonal aggression and the risky lifestyle of hunter-gatherers—involving their unsettled way of life and exploitation of varied, wild resources, including some hunting of larger animals. However, the very few such injuries (14 of 309 individuals, or about 4.5 percent) found in our Mesolithic sites (which comprise about 75 percent of all the Portuguese Mesolithic series) do not match this expectation, nor do they match the expectation of a continuum of aggression positively correlated with population density.

In all, the traumatic lesions detected primarily appear to represent accidental injury rather than group conflict (Cunha et al. 2004).

LATE NEOLITHIC/CHALCOLITHIC

Though the fragmentary nature of the human remains can contribute to an underestimation of the traumatic events, our results point to homogeneity within the Late Neolithic/Chalcolithic.

Depressed fractures in a total of twelve adult cranial vaults were detected in skeletal materials from several sites. Prevalence could not be determined, because we are dealing with cranial bone fragments (Silva 2002, 2003b).

Discriminating between violence and accidents is difficult. Though violence cannot be excluded in the analysis of the injuries visible in these cranial vaults, the irregular topography at some sites suggests that falls may be the more plausible explanation. Indeed, depressed fractures are more common in individuals living in mountain sites, such as Serra da Roupa and Dolmen de Ansião.

Trepanations seem to be very rare in this period when the cranial vaults are compared to those of other coeval European countries. Only twenty-two trepanations or possible trepanations, mostly indicated by scraping or incision, have been reported from the Late Neolithic through the Early Bronze Age in Portugal. This low number of cases described may partly be a consequence of the practice of collective and sometimes secondary burial, resulting in disarticulation and poor preservation (Silva 1999, 2003a).

The prevalence of traumatic injuries affecting the postcranial bones is low, with only twelve cases detected. Some healed lesions led to secondary osteoarthritis. Femurs, ulnas, tibias, metatarsals, and metacarpals are the affected bones (Silva 1996a, 2002, 2003b).

Degenerative Lesions

MESOLITHIC

It is important to emphasize that in many cases, taphonomic alterations preclude the evaluation of both muscle-insertion sites in bone and articular surfaces.

We cannot yet quantify degenerative diseases in the Mesolithic. All we can say is that in Mesolithic skeletons, with the exception of a severe lesion on a temporomandibular joint (Cunha et al. 2003), all osteoarthritic lesions are both infrequent and mild, a fact that might be related to the general demographic profile of the series. The samples are characterized by a near absence of old individuals. In addition to age, the main etiological factor for osteoarthritis (OA) is biomechanical effort. However, in these populations, most osteoarthritic lesions observed are secondary (that is, related to trauma). The pattern seems to suggest that these people were not subject to heavy and repetitive physical activities.

Enthesopathies also are not common, suggesting again a lack of repetitive or strenuous physical tasks. We did not detect cases of extreme forms of insertion site remodelling.

LATE NEOLITHIC/CHALCOLITHIC

The general prevalence of osteoarthritis seems to be low, though there are some cases of extremely severe eburnation to be noted (Silva 1996a, 1996b, 1999, 2002).

Differential preservation and small sample sizes commonly prevent comparisons of the different samples or even of the pattern of lesions within each one. Nevertheless, some samples (such as the one of Hipogeum São Paulo II) seem to show a trend towards more OA in specific joints, particularly those of the carpal bones (Silva 2002).

Cervical spine OA lesions are relatively common and perhaps are related to carrying heavy loads on the head, which was a common practice among the farmers.

In the Late Neolithic bones, the muscular insertion sites (entheses) that are generally most affected are the Achilles tendon insertion and laminal spurs at the thoracic level.

MESOLITHIC VERSUS LATE NEOLITHIC

Hunter-gatherers are often described as highly mobile and physically active, whereas farmers are described as sedentary and more inactive. Larsen (1997, 2002) pointed out that there is a tendency, in some regions, for more OA in skeletons of hunter-gatherers than in farmers. However, there is a higher degree of variation in prevalence and severity, suggesting that OA is linked to localized circumstances involving a complex interplay between lifestyle, culture, and environment (Larsen 1997, 2002). In our sample, the existence of several eburnation cases in the Late Neolithic and the near absence of such severe cases in the Mesolithic seem to reflect heavier workloads in the later, agricultural populations.

Infectious Diseases

MESOLITHIC

In the absence of a good sample, we can provide only general comments about infection. But there are not many cases of infection in Mesolithic samples to be mentioned. Moreover, they are not severe. The lesions observed reflect periostitis, mainly remodeled and affecting lower limb shafts (tibias in particular).

LATE NEOLITHIC/CHALCOLITHIC

The prevalence of infection is again low: almost always fewer than 10 percent of the bones exhibit periostitis. The exception is Paimogo I, where the tibias exhibit periostitis much more frequently (left: 21/104, or 20 percent; right: 18/111, or 16 percent). That the majority of the lesions are healed suggests chronic occurrence.

São Paulo II (SP) is the sample in which more types of bones are affected and more lesions are active. It is the only series in which infectious lesions are found in the thoracic bones. Several rib fragments are affected. A left clavicle exhibits extensive layers of new bone formation. The same formation affects a scapular bone. The nature and location of these lesions suggest tuberculosis as one possible etiology (Silva 2002).

Among juveniles, the prevalences are generally low. One exception is a case from Cabeço da Arruda II, in which an iliac bone of a subadult (1.5–2.5 years old) exhibits extensive new bone deposition (Figure 11.5).

MESOLITHIC VERSUS LATE NEOLITHIC

Generally, populations undergoing adaptive shifts from foraging to part-time or intensive farming show an increase in the prevalence of periostitis and bone

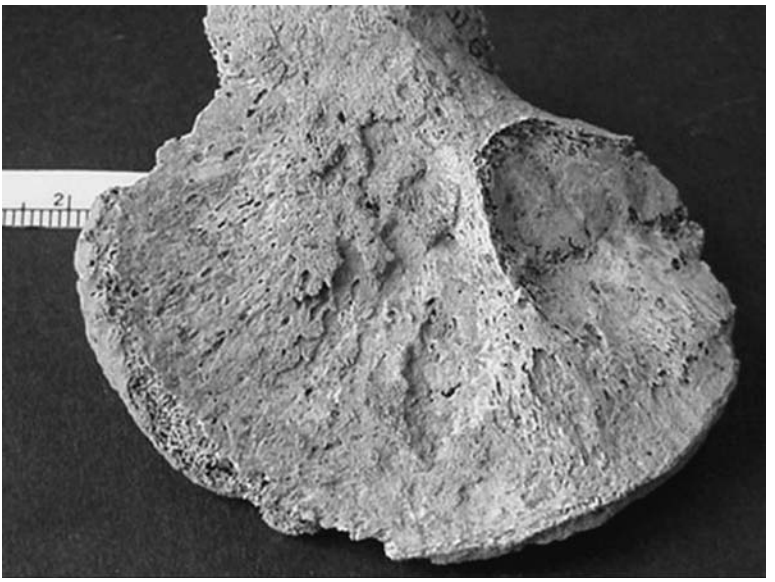

Figure 11.5. Left ilium (CA II 986) of a 1.5–2.5-year-old infant from the Cabeço da Arruda II site, Portugal, displaying layers of new bone formation.

infection (Larsen 2002). Our data seem to be in accordance with the assumption that Late Neolithic people should present a higher prevalence of these lesions.

Trends Seen from the Mesolithic to the Late Neolithic/Chalcolithic in Portugal

The attained results allow us to delineate some trends.

There was an increase in caries and a decrease in dental wear severity. Moreover, the patterns of Mesolithic and Late Neolithic people also were different. Whereas the former tend to present a flat wear on their molars, the latter ones exhibit more variation, without a typical pattern.

Our results do not suggest that the last hunter-gatherers were more affected by trauma than the farmers were. There does not appear to be a high percentage of Mesolithic individuals displaying signs of trauma.

The frequency of degenerative lesions increased from the Mesolithic to the Late Neolithic/Chalcolithic. Furthermore, certain articulations were more affected among the farmers, namely, cervical and shoulder joints.

Finally, the prevalence of infectious lesions increased during the period in question.

12

The Political Ecology of Health in Bahrain

JUDITH LITTLETON

Since circa 4500 BP, the inhabitants of Bahrain have been active participants in networks of both local and international trade. The varying patterns of trade, combined with environmental fluctuations, have created a suite of stressors impacting individual health.

There have been ongoing excavations of Bahrain's archaeological sites since the 1950s. Urban expansion beginning in the 1980s threatened numerous sites; to cope with this expansion, the Directorate of Archaeology undertook extensive excavations of cemetery sites. The result is a series of human remains from major periods between the first establishment of a "state" system to the middle Islamic period, a time span of around three thousand years. These samples provide the opportunity to explore the relationships between political economy, environmental change, and health. I argue here that the process of adaptation to ecological and political change rather than change per se is the major determinant of health.

Background

GEOGRAPHY, CLIMATE, AND ECOLOGY

Bahrain comprises a series of small islands off the east coast of Saudi Arabia in the Arabian Gulf (Figure 12.1). Most human settlement and, as a consequence, archaeological investigation have focused on the largest island, Awal. Two factors have played a major role in its history: the supply of underground water and its position on the major seagoing route between Mesopotamia and the Indian subcontinent.

The main island is surrounded by a narrow coastal plain approximately 9 kilometers wide on the northern edge and narrowing down to 3–4 kilometers wide on the eastern and western sides. The coastal plain rises to barren limestone slopes around a central depression within which lies the island's "mountain"—Jebel Dukhan, with a peak of 135 meters above sea level. Cultivation has been restricted to the coast (Dalongeville 1999). The only other arable land is at the mouth of some of the wadis (generally dry creeks). The environment of

Figure 12.1. Map with location of Bahrain in the Persian Gulf.

the island is arid; limited rainfall makes the island totally dependent on underground water (C. E. Larsen 1983).

In the north of the main island, water from aquifers on the Arabian mainland surface in numerous artesian springs. Prior to recent overexploitation of water, springs at several locations provided sufficient water for irrigation, allowing oasis agriculture.

Spring-water levels have fluctuated in the past because of sea-level changes, climatic change, and the extent of aquifer recharge in Arabia (C. E. Larsen 1983, 1986). When water supplies are greatest, settlements could have extended farther south and farther inland. The best agricultural conditions occurred in the Bronze Age; the Iron Age would likely have seen a significant contraction of agriculture, whereas the Hellenistic and mid-Islamic periods potentially approached the Bronze Age in terms of suitability for agricultural production.

Dental pathology suggests that these fluctuations reflect agricultural practices shifting from mixed intensive agriculture and pastoralism to more-intensive irrigation agriculture during the Iron Age and Hellenistic periods, followed by more-extensive cereal production in the mid-Islamic period (Littleton and Frohlich 1989). Environmental practices should have had a direct impact on rates of malaria, which should have been most common in the Iron Age and Hellenistic periods.

HISTORY

The island's populations have never exclusively relied on agricultural production. Settlement was intermittent until the Bronze Age, around 4500 BP, when a small settlement was established on the north end of the island and grew rapidly. By circa 4250 BP, there was a walled township with smaller dispersed settlements across the island. At the same time, a large temple (the Barbar temple) was built nearby, suggesting increasingly centralized authority. Literary and archaeological evidence suggest that the center of the Dilmun state had moved to the island (circa 4400 BP) and served as a center of long-distance trade (Crawford 1998; Hojlund 1989; Potts 1990a).

Burial patterns reflect a centralized pattern, moving from dispersed mounds to distinct mound fields related to specific settlements. There was, however, one mound field in the center of the island, Ali, where approximately 20 extremely large mounds (20–25 meters high), called the "Royal Tumuli," have been interpreted as an elite burial place (Breuil 1999; Hojlund 1989). Such mounds form only a very small percentage of the estimated 80,000–100,000 burial mounds dating to this period (Frohlich 1986). The majority of burials suggest greater investment in tomb architecture in a small number of graves. The evidence suggests an independent prosperous state with a small elite but otherwise limited inequality.

Circa 3800 BP, the disappearance of the Indus civilizations, the economic withdrawal of southern Mesopotamia, the rise of competing trading centers, and possibly water changes on the island seem to have triggered an economic and strategic decline. Dilmun seems to have then come under direct Mesopotamian influence. Ultimately, the island became a Babylonian colony (Lombard 1999b). Most of the graves from this period are mixed multiple interments with poor preservation.

The fall of the Kassite Empire means that Bahrain is poorly known in the Iron Age between 3250 and 2750 BP. Nominally, Dilmun was under Assyrian control, but the distance from this center of power suggests that control was minimal. During this period, the island appears to have rebuilt local trade links and businesses until circa 2700 BP, when it was again drawn into Mesopotamian affairs, initially as a small, prosperous, autonomous kingdom and then more directly under control of the Neo-Assyrian regime (Lombard 1999a).

After conquest by Alexander the Great, Bahrain during the Hellenistic period (2300–1750 BP) became part of a common cultural sphere. There may have been a foreign enclave on Awal Island (Potts 1990b; Salles 1996). Certainly, Greek cultural influence is noticeable. Burials from this period testify to a range of material culture including some very wealthy graves, particularly in the north. In contrast, graves from southern sites were less rich and displayed more reuse. There is a gap in the historical record following circa 1750 BP. By

Table 12.1. Samples from the Island and Conditions at the Time

Period	Sample Size	Date	Conditions
Bronze Age	*N* =57 (4 subadults)	c. 4250–3750 BP	Increasing involvement in international trade; mixture of gardening and pastoralism; small elite
Iron Age	*N* = 82 (31 subadults)	c. 3000–2750 BP	Small business kingdom, local trade; contraction of water, date palm cultivation and fishing but local economy largely unknown
Hellenistic	*N* = 1,051 (631 subadults)	c. 2300–1400 BP (most from 2300 to 1750 BP)	Involvement in trade under possible foreign control; more-intensive agriculture, high water levels; expenditure but inequality in burial practices
Mid-Islamic	*N* = 39 (13 subadults)	c. 800–500 BP	Local tribal hierarchy under variable control of Persian dynasties; high water levels, more extensive agriculture; moderate prosperity based on historical records

the middle Islamic period, however, local tribal hierarchies had been established and had become involved in local Gulf trade.

These historical sequences and how they related to human remains are summarized in Table 12.1. The shifting environmental circumstances, particularly the hypothesized reduction in water levels during the Iron Age and Hellenistic periods, should have had some impact on the health of the local populations. The marginal position of the island's economy during the Iron Age (and possibly again in the mid-Islamic period) can also be predicted to have had an impact. In contrast, the other three periods are hypothesized to have been relatively prosperous, with the greatest evidence for wealth coming from the Hellenistic graves; inequality in burial practices seems to have varied, however.

The small size of the island and tight geographical relationship between the samples on the island provide an opportunity for examining the relative impacts of environment and political change on populations.

Materials

The sample sizes used in these analyses are listed in Table 12.1, which provides the maximum number of individuals. Sample sizes for particular analyses (Tables 12.2–12.8) are much smaller.

The Bronze Age sample comes exclusively from burial mounds at Hamad Town (Frohlich 1986). The Iron Age sample comes from Ali Mound 1, Cham-

ber 1, a multiple tomb excavated in 1982 and dated on the basis of associated pottery and seal types. The Hellenistic period sample is the most diverse, comprising skeletons from several sites: DS3, Saar, Karannah, and Abu Saybi (Littleton 1998; Herling 1994). The Islamic skeletons are dated to the mid-Islamic period on the basis of their stratigraphic location (Kervran 1990).

Methods

This analysis rests on standard cranial and postcranial measurements collected using definitions by Bass (1981). Because of varying preservation, adults are divided into two categories: young (up to 30 years of age) and mature (over 30 years of age).

Cribra orbitalia (CO) and porotic hyperostosis (PH) were recorded using the scoring system of Nathan and Haas (1966). The status of the lesion, whether active or remodelled, was also noted. Lesions of infectious trauma were likewise evaluated as active or healed, and linear enamel hypoplasia (LEH) was observed on incisors and canines. Defects were recorded when they occurred upon the antimeres and assigned to the age/crown segment (Hillson 1992).

Because of the small sample sizes, statistical analysis is restricted to comparison of individual measurements. Differences between samples were tested through ANOVA using a Boneferroni post hoc test to correct the significance level and account for the multiple comparisons undertaken. The advantage of post hoc tests is that they identify the source of the significant differences. All analyses were undertaken using SPSS v10.

Results

MORTALITY

Mortality is the ultimate indicator of stressful living conditions, but it is difficult to assess with skeletal remains (Wood et al. 1992). The Hellenistic sample is representative, based on 80 percent of a cemetery excavation; the others are harder to evaluate. Subadult mortality for the Bronze Age is underrepresented. Subsidiary graves were apparently set aside for subadults, and their frequency potentially provides a more accurate indicator of subadult mortality (Table 12.2). Iron Age children and adults were buried differently, but the age distribution of children in this sample is as might be reasonably expected (most less than 1 year of age and declining numbers thereafter, to 15 years of age). The rate of subadult mortality parallels that of the Bronze Age. Hellenistic subadult mortality is significantly greater: 60 percent of all deaths at one site with very

Table 12.2. Age and Sex Distribution of Deaths (%) within the Samples

	Subadults	Males	Females	All Adults	*N*
Bronze Age					
Skeletons	7.0	70.6	29.4	93.0	57
Graves	28.0	—	—	72.0	489
Iron Age	37.8	52.8	47.2	62.1	82
Hellenistic	60.1	49.7	50.3	39.9	1,051
Islamic	33.4	65.4	34.6	66.6	39

high levels of infant mortality. In the Islamic period, again the sample is small and there is perhaps 33 percent underrepresentation of infants.

Biased ratios of male to female skeletons reflect the inadequacies of the Bronze Age and Islamic samples. However, mortality conditions for all appear to have been worst in the Hellenistic period, compared to moderate levels of subadult mortality in the later periods. The high proportion of infants in the Hellenistic period may reflect high fertility. Modeling, however (using alternative rates of population growth), still indicates a very high level of infant mortality during this period, particularly obvious in the ratio of deaths for subadults less than 1 year old versus deaths in the age group of 1–4 years old (Wills and Waterlow 1958).

STATURE

Long bone measurements allow evaluation of trends in height and sexual dimorphism (Tables 12.3 and 12.4). Because sample sizes for the Iron Age are very small, this period was not included in statistical comparisons but is shown for comparative purposes.

The length of the long bones (Table 12.3) did not change significantly over time for males on Awal Island, although minor fluctuations across the periods can be distinguished. In contrast, there are significant differences in the length of female long bones over time. In the Iron Age and Hellenistic period, arms and legs are both shorter (significantly so for the Hellenistic period) than in either the Bronze Age or Islamic period. Length then increases in the Islamic period, although generally not to the Bronze Age female values.

Shape and robusticity show few differences between the periods (Table 12.3). For males, the only significant difference is in the shape of the femoral shaft. The proximal shaft is significantly narrower medio-laterally in the Islamic period than in the preceding periods, resulting in a reduced robusticity for the proximal femur; there is no corresponding change in the midshaft dimensions.

Table 12.3. Long Bone Length for Males and Females (*N*)

	Bronze Age mm (*N*)	Iron Age mm (*N*)	Hellenistic mm (*N*)	Islamic mm (*N*)
Males				
Humerus	318.6 (14)	—	310.2 (46)	316.1 (10)
Ulna	271.5 (10)	291.0 (2)	264.5 (28)	270.3 (8)
Radius	249.5 (13)	264.0 (1)	246.7 (26)	246.9 (10)
Femur	423.7 (12)	430.0 (1)	435.4 (38)	448.0 (6)
Tibia	370.9 (14)	371.0 (1)	373.1 (24)	383.4 (5)
Fibula	346.8 (4)	367.0 (1)	362.3 (7)	362.0 (6)
Height	165.9 (12)	165.3 (1)	166.6 (38)	169.5 (6)
Females				
Humerus***	306.9 (10)	269.0 (2)	287.6 (51)	296.0 (8)
Ulna**	263.0 (4)	242.0 (1)	239.8 (33)	248.1 (8)
Radius***	243.8 (6)	230.0 (4)	219.8 (41)	226.6 (8)
Femur*	423.0 (15)	397.0 (1)	405.8 (48)	416.5 (2)
Tibia*	358.9 (11)	334.0 (1)	336.5 (27)	358.0 (3)
Fibula	347.3 (6)	362.0 (1)	334.7 (9)	347.0 (2)
Height	158.6 (15)	152.1 (1)	154.3 (48)	157.0 (2)

Note: *N* refers to the number of analyzable elements.
* $p<.05$; ** $p<.01$; *** $p<.001$.

Table 12.4. Level of Dimorphism in Postcranial Dimensions of Size, Shape, and Robusticity

Element	Bronze Age	Iron Age	Hellenistic	Islamic
Maximum Length				
Humerus	3.8	—	7.9	6.8
Ulna	3.3	20.2	10.3	8.9
Radius	2.3	14.7	12.2	8.9
Femur	2.3	8.3	7.3	7.6
Tibia	3.3	11.0	10.9	7.1
Fibula	-0.2	1.4	4.3	4.3
Leg (fem. + tib.)	0.1	9.6	9.7	7.2
Joint Surface				
Humerus head—vert.	3.9	—	16.8	—
Humerus head—trans.	—	6.6	—	16.9
Epicondylar breadth	9.9	7.5	14.6	12.3
Femur head diameter	8.7	13.1	15.6	19.5
Bicondylar breadth	6.0	—	10.4	22.8
Shaft Robusticity				
Subtrochanteric	7.1	3.6	9.7	6.4
Midshaft femur	9.5	4.3	7.9	5.7
Tibia midshaft	—	10.2	7.02	—

Note: Dimorphism is calculated using the following formula: (male av. - female av.) / (female av. × 100). Vert. = vertical; trans. = transverse; fem. = femur; tib. = tibia.

Among females, the reduction in stature is also reflected in the size of the joint surfaces: femoral and humeral head diameters and epicondylar and bicondylar breadths are all significantly smaller in the Hellenistic period than in either the Bronze Age or Islamic period. There are, however, no significant differences in shaft dimensions.

There is a different pattern of dimorphism in postcranial dimensions among periods (Table 12.4). In the Bronze Age, there is limited dimorphism in postcranial shape only. In the small Iron Age samples, shaft dimensions show no significant dimorphism. In contrast, given the reduced height and robusticity of females in the Hellenistic period, all postcranial dimensions are significantly dimorphic. Similarly, in the Islamic period, all postcranial dimensions of size (length of long bones and size of joint surfaces) are significantly dimorphic, but the shaft robusticity measures are not. Thus, there is a shift from limited dimorphism in the Bronze Age, to greater dimorphism in the Iron Age, to size and robusticity dimorphism in Hellenistic females, to dimorphism only in size again in the Islamic period.

Shaft robusticity measures of the femora and tibiae show similar levels of dimorphism for the Bronze Age and Hellenistic periods but lower levels for the Islamic period.

Dimorphism is low in the Bronze Age in all dimensions, yet absolute stature is large. By the Hellenistic period, however, there has been a significant decrease in female stature and robusticity while male values have stayed relatively static. Clearly, conditions did not worsen for males but did for females, despite their presumed greater buffering against environmental stress. In the Islamic period, stature increases for both sexes, suggesting some amelioration of circumstances, but the level of dimorphism remains constant, suggesting that although overall conditions may have improved, those specifically affecting females did not.

There are few changes in cranial morphology over time (Littleton, in press). The minor changes observed do not argue for a major population replacement on the island, where, in any case, such influxes are most likely to have come from those areas with which there was long-term genetic exchange.

POROTIC HYPEROSTOSIS AND CRIBRA ORBITALIA

As a marker of childhood anemia (from multiple causes), PH should show some fluctuations over time. Unfortunately, with the exception of the Hellenistic period, samples of subadults are too small to permit confident analysis of the incidence of this condition. Cribra orbitalia occurs in each period at what appear to be similar rates, although all children who died during the Islamic period appear to have had pitted orbits (Table 12.5). The rate of healed lesions

Table 12.5. Rates of Cribra Orbitalia and Porotic Hyperostosis among Subadults

	CO		PH	
	%	*N*	%	*N*
Bronze Age	50.0	2	0	3
	0 healed	—	—	—
Iron Age	59.3	27	30.4	26
	7.4 healed	—	8.6 healed	—
Hellenistic	57.1	379	45.3	170
	13.2 healed	—	23.9 healed	—
Islamic	100.0	11	53.9	13
	27.3 healed	—	23.1 healed	—

Table 12.6. Rates of Cribra Orbitalia and Porotic Hyperostosis among Adults

	All		Males		Females	
Period	%	*N*	%	*N*	%	*N*
CO						
Bronze Age						
All	48.9	45	53.3	30	28.6	14
% severe	17.8	—	—	—	—	—
Iron Age						
All	66.7	42	60.0	15	80.0	15
% severe	28.6	—	—	—	—	—
Hellenistic						
All	39.0	166	37.0	78	50.0	88
% severe	17.6	—	—	—	—	—
Islamic						
All	25.0	24	23.5	17	28.6	7
% severe	8.3	—	—	—	—	
PH						
Bronze Age	15.2	49	16.7	30	13.3	15
Iron Age	12.7	55	0	19	26.7	15
Hellenistic	10.5	171	—	—	—	—
Islamic	16.7	24	12.5	16	25.0	8

among the children varies, but this is partly attributable to differing age structures in the samples, so it cannot be seen as significant.

PH occurs in a third of the Iron Age subadults and in half of the Hellenistic and Islamic subadults, among whom severe lesions and extensive bossing were observed, suggesting an increasing prevalence of anemia (of varying causes) over time. The difference comes when looking at the adults. It is argued that PH develops during childhood (Stuart-Macadam 1991), so subadult frequencies represent those children who died while experiencing or after experiencing the condition. Adult frequencies represent the number of survivors who

had developed cribra orbitalia or porotic hyperostosis as a child, so the vast majority of lesions are healed.

The Bahrain samples show a different trend (Table 12.6): higher frequencies of CO in the Bronze Age and Iron Age and lower frequencies in the Hellenistic and Islamic periods. There are two explanations for this variation from the commonly predicted pattern. One is that in the Bronze Age and Iron Age samples, CO does not represent a significant contribution to subadult death, whereas in the Hellenistic and Islamic periods it does. The alternative is that children experiencing this condition are overrepresented among those who died in the Hellenistic and Islamic periods. The two explanations are not mutually exclusive. Stress may impact one group more severely than another within the same society, but complete isolation from stressors is not going to occur for any group.

The gender disparity in the incidence of CO suggests inequality among children in both the Hellenistic and Islamic periods. In the Bronze Age while more males than females had CO there are no differences in the rate of PH. By the Iron Age there is dimorphism in the pattern of cribra orbitalia and porotic hyperostosis, with females being affected more than males. Given the presumed lesser susceptibility to childhood anemia of female children, this suggests true disparity in treatment of children by sex.

In the Hellenistic period in particular, what appears to happen is that in half of the children who died, PH was so extensive that few recovered from it during childhood. Presumably, these children died from chronic conditions, but there are still 50 percent of children who died from more-acute causes and as a result exhibit no stress indicators upon their bones. The skeletal remains of surviving adults are much less severely affected by either CO or PH. However, more women than men survived with lesions, so anemia in this population was not only a significant factor in selective mortality but was also disproportionately common among female children. In the Islamic period, more females than males are determined to have been affected by cribra orbitalia and porotic hyperostosis, a pattern that is similarly suggestive of sex-specific treatment, though the higher prevalence of stress indicators may indicate more-chronic conditions causing death, rather than acute conditions. The level of data at the moment cannot distinguish between these two, however, and the significance of the difference in CO levels between Hellenistic and Islamic children cannot be determined.

LINEAR ENAMEL HYPOPLASIA

Linear enamel hypoplasia (LEH) is extremely common among all four samples, with no significant differences between them in terms of frequency or age of

Table 12.7. Frequency of Linear Enamel Hypoplasia among Permanent Dentitions

	Subadults		Adults	
Period	%	*N*	%	*N*
Bronze Age			96.4	28
Iron Age	0	1	100.0	4
Hellenistic	88.9	18	95.0	60
Islamic	100.0	1	90.0	20

development (Table 12.7). The highest prevalence occurs between ages 2 and 4 (represented by age units C and D in Figure 12.2). Hellenistic subadults, however, display a different pattern—with LEH occurring at higher rates at earlier ages—suggesting that earlier stress episodes may have contributed to their mortality risk. This corresponds to the high prevalence of infant and early childhood mortality in this sample, in addition to active porotic hyperostosis among young children.

Discussion

Although complicated, the indicators of subadult mortality, stature, porotic hyperostosis, and LEH do tend to show a consistent picture (summarized in Table 12.8).

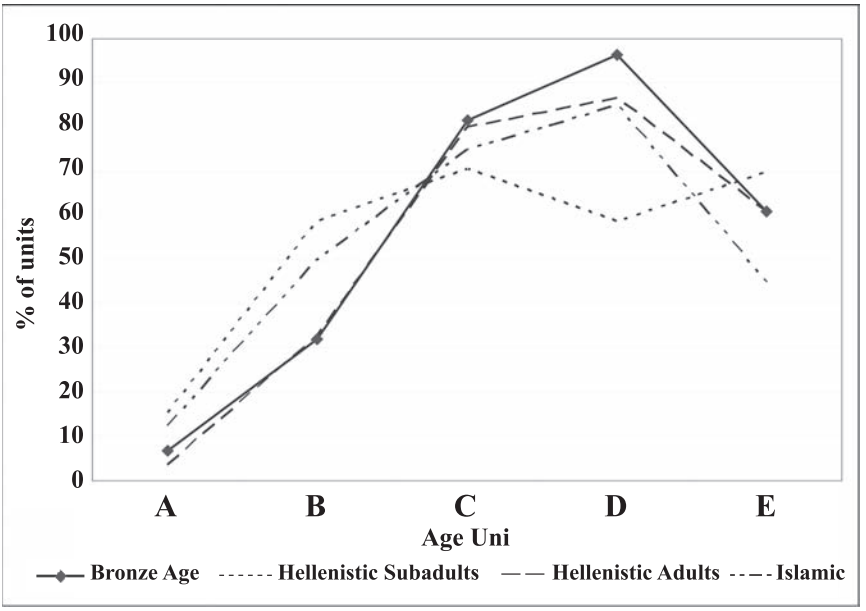

Figure 12.2. Distribution of hypoplasia by age units representing development from one to six years of age in populations from Bahrain.

Table 12.8. Summary of the Patterns of Pathology and Mortality among the Samples

Indicator	Bronze Age	Iron Age	Hellenistic	Islamic
Subadult mortality	Low-moderate	Moderate?	High	Moderate
Stature	Tall	Short	Short females	Taller
Dimorphism	Low		High	Low-moderate
CO/PH	Moderate	High	High (subadult)	More adult PH
LEH	Frequent	Frequent	Frequent, earlier among subadults	Frequent

Note: CO = cribra orbitalia; PH = porotic hyperostosis; LEH = linear enamel hypoplasia.

In the Bronze Age samples, subadult mortality is moderate, there is only slight sexual dimorphism, people are tall, and there are moderate levels of cribra orbitalia and porotic hyperostosis. Males more frequently demonstrate evidence of porotic hyperostosis than females do, and most lesions are fairly mild.

In the Iron Age samples, there is a potential increase in subadult mortality, a decrease in stature, and higher frequencies of CO and PH amongst subadults and females. Sample sizes are small however.

In the Hellenistic period, subadult mortality is higher, sexual dimorphism has increased (although there has been no significant change in male dimensions), and females are more frequently affected by porotic hyperostosis than are males. There are several indicators of high mortality concentrated upon children less than two years of age.

In the Islamic period, subadult mortality may be reduced slightly. The same degree of sexual dimorphism in height and prevalence of PH occurs, but height has increased for both sexes.

In the Bronze Age, there is little paleopathological evidence of nutritional shortage. Average heights for both sexes show no sign of stunting, and environmental reconstructions suggest a prosperous economy of mixed agriculture. Sexual dimorphism is reduced, but not by male stunting.

In the few analyzable Iron Age samples, there are no statistically significant differences in stature from the earlier period, the percentage of children with PH has increased, and more females than males are affected by CO and PH. The sample sizes for the Iron Age are too small to permit definitive conclusions, but there may have been some worsening of health conditions, possibly from an increased prevalence of malaria, less pastoralism, and lower water levels.

In the Hellenistic period, marked reduction in female height and robusticity occurs, evidence of anemia is more severe in females than males; and subadult

mortality is extremely high. This seems to suggest the full interaction of infection, immunity, and nutrition. Infection, including malaria, has a severe impact both upon immune response and upon nutrient absorption, clearly demonstrated by evidence for rickets among Hellenistic infants (Littleton 1998).

In the Islamic period, both males and females appear to have reached more of their growth potential and mortality levels probably decreased slightly, but male/female dimorphism is still evident in stature and anemia. Potentially, the severity of infection—particularly acute infection—lessened (given that all children who died had stress indicators upon their bones). The easing of acute infections may have allowed a greater nutritional input, permitting greater adult stature.

When these data are compared with ecological change, what is not explained is why similar ecological conditions in the Iron Age, Hellenistic period, and possibly Islamic period had differing impacts. By the Hellenistic period, water levels had decreased to low levels and mortality had become high (possibly because of the effects of malaria), yet the impact is apparent primarily on females: female height and robusticity are reduced relative to those of males, and females exhibit evidence of having suffered more anemia, suggesting reduced care of female children on a broad scale.

A comparison of demographic and health patterns between two settlements—one north, one south (in a marginal area)—suggests that living conditions were worse to the south (Littleton 1998). Grave goods and finds in the island's main settlement suggest involvement in luxury trades and extensive foreign influence during the Hellenistic period (Herling 1999), possibly accentuating class differences (compared with the Bronze Age, during which there is relatively little indication of status differences).

By the Islamic period, it seems that mortality may have lessened and adult stature increased, suggesting the availability of more resources. The degree of male/female dimorphism, however, has not decreased, and differential access to resources appears to have still existed.

Conclusion

In Bahrain, there seems to have been a transition from a non-irrigating to an irrigating form of agriculture, and as a result, health declined; one of the major stressors would have been the increasing prevalence of malaria. However, this reflects both environmental and political factors involving shifts in trade patterns. Repeated shifts from international to local trade and back affected the balance of power and that inequality was reflected both between and within communities and between the sexes.

Acknowledgments

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13

Skeletal and Dental Health and Subsistence Change in the United Arab Emirates

SOREN BLAU

This chapter examines changes in skeletal and dental health from the late seventh/early sixth millennium BP to the Late Pre-Islamic period of the first century AD in the United Arab Emirates (UAE), whose geography and climate provide an interesting background for studying changes in subsistence and health over time.

The UAE (approximately 77,700 square kilometers), on the southern shores of the Arabian/Persian Gulf, is in a subtropical arid zone. It essentially has only two seasons: summer and winter. Summers (May to September) are exceptionally hot, with temperatures reaching up to 45°C. Humidity averages between 37 and 62.9 percent. Winters (December and February) are cooler, with temperatures averaging 10–30°C and humidity averaging between 64.6 and 73.3 percent (Potts 1990a: 22). Climatic conditions have altered relatively little in the last 5,000–6,000 years (Potts 1997: 40; Potts 1990a: 131–32; Sanlaville 1992). There are four main environmental regions: uncultivable and uninhabitable sandy desert comprising two-thirds of the territory; coastal and desert regions; the mountains; and the alluvial plains.

Prehistoric settlement on the gulf and east coasts of the UAE apparently began in the seventh millennium BP and extended into the fourth millennium BP. Early settlers appear to have seasonally exploited resources both on the coast and in the interior (Potts 1998a). In the last centuries of the third millennium BP, there is no evidence of a site on either coast of the UAE (Potts 1998b). Interior sites, however, have evidence of a wide variety of imported goods, suggesting continued contact with the coast.

Materials and Methods

Long periods of dryness followed by short bursts of torrential rain and burial practices involving inhumation, removal, reinterment, cremation, and tomb reuse are problematic for skeletal preservation (Blau 2001a, 2001b). While there is evidence of articulated skeletons at sites across the UAE (for example,

Table 13.1. Samples Used in the Study

Site	Period	Date	Source	Skeletal Elements	Crania	Teeth[a]
Site 2	Ubaid	late 7th/ early 6th mill. BP	Strongman 1994	0	0	697
Al-Sufūh	Umm an-Nar	ca. 4400–4300 BP	Benton 1996: 19			304
Tomb 1				1,245	8	
Tomb 2				3,767	22	
Tomb 3				3,245	27	
Tomb 4				52	3	
Total				8,309	60	
Unar 1	Umm an-Nar	4400–4200 BP	Blau 1998: 78	0	0	279
Mowaihat	Umm an-Nar	ca. 4300–4100 BP	Al-Tikriti 1989: 97	3,307	57	433
Unar 2	Umm an-Nar	ca. 4300–4100 BP	S. Mery & R. Carter pers. comm.	12,982	2	55
Tell Abraq	Umm an-Nar	ca. 4000 BP	Potts 1993a: 120	0	0	628
Sh. 602	Wadi Suq	ca. 3500 BP	D. Kennet pers. comm.	700	2	38
Sharm	Wadi Suq	ca. 3200 BP	Barker 1997	2,989	0	50
Wa'ab	Iron Age	late 4th/ early 3rd mill. BP	Phillips 1997: 210	0	0	39
Naslah	Iron Age II	3100–2600 BP	Magee 1996a: 245	0	0	172
Fashgha	Iron Age	late 4th/ early 3rd mill. BP	Phillips 1997: 211	0	0	78
Ed Dur	Late Pre-Islamic	ca. 1900 BP	Stone 1996	0	0	212

[a] In situ and loose.
[b] Reused in the Iron II period.

Blau 2001c; Strongman 1994; Hellyer 1998), most archaeological skeletal remains are fragmentary, disarticulated, or poorly preserved. As a result, diagnosis of patterns of pathology in any one individual skeleton is limited, as is estimation of the age and sex of individuals.

The materials include collections of relatively complete human skeletal remains from five sites dating from the fifth to the fourth millennia BP and dentition from twelve sites from the late seventh/early sixth millennium BP to the second millennium BP (Table 13.1).

The Ubaid Period (Late Seventh/Early Sixth Millennium BP)

Evidence for settlements dating to the Ubaid period is limited (perhaps because they were seasonal and relatively ephemeral). Most remains come from graves. Although inland sites have been found, most are coastal or on ancient shorelines. Some settlements contain buildings of beach rock (*farush*); others are mere scatters of flint (Kiesewetter 2003; Crawford 1998). The latter were probably winter camps of pastoralists grazing their herds in the interior but

exploiting marine resources during the summer (Uerpmann et al. 2000). Remains of fauna such as sheep, goats, and cattle as well as wild ass, the Arabian gazelle, and the Arabian thar were also found (Potts 1993b: 180; Uerpmann 2003). The burial sites typically include finely worked flint, shell, stone beads, animal bones, and Ubaid pottery.

Evidence for diseases such as cribra orbitalia have been recorded at late seventh/early sixth millennium BP sites (Strongman 1994; Kiesewetter 2003; Coppa et al. 1985), but small samples and minimal reporting restricts comparisons. Evidence from Jebel Buhais 18, however, suggests that the frequency of anemia (3.2 percent) in adults (n=95) was low (Kiesewetter 2003: 42).

The dental sample comes from a single site, Site 2, located on the west coast of the UAE. Remains recovered at the site include shells, fish, and mammal bones as well as flint tools and shell beads (Hellyer 1998: 30). Human articulated and disarticulated burials were recovered, but no settlement has been located.

The Umm an-Nar Period (Fifth Millennium BP)

In the fifth millennium BP, the number of gravesites increased and permanent settlements appeared, often located close to copper sources. The prominent features include circular stone or mud-brick fortlike buildings up to 40 meters in diameter that were often associated with stone wells. Many settlements had walls and ditches possibly serving defensive purpose (Potts 1993b: 187), and they are often associated with collective burials. Less impressive domestic and industrial buildings were clustered around the towers. The monumental tower structures with the flimsier surrounding houses suggest a degree of social differentiation (Crawford 1998: 113).

While only a few tombs, such as those at Tell Abraq and Hili, are located near domestic structures (possibly suggesting that other settlement sites have not yet been discovered), tombs from this period are located throughout the Oman Peninsula in coastal, piedmont, and desert (oasis) environments (Blau 2001b). Lavish grave goods indicate extensive trade with Mesopotamia and the Indus Valley.

Most sites suggest mixed economies that involved farming, fishing, and hunting. The most important sources of protein came from domesticates such as sheep, goat, and cattle (Potts 1998a). Domesticates also include the date palm (Wilcox and Tengberg 1995), providing necessary shade, as well as wheat and barley, processed by grinding stones. Although copper had been exploited in the UAE by the late sixth millennium BP, extraction techniques improved considerably in the UaN period. Various bronze artifacts have been found (Crawford 1998).

The UaN skeletal and dental samples come from five sites: al-Sufūh, Unar 1, Unar 2, Mowaihat, and Tell Abraq. Al-Sufūh is located on the west coast of the UAE near the modern city of Dubai. The site consists of mortuary remains, scanty evidence of settlement, pottery, shells and faunal material, and concentrated areas of ash and burnt material, probably for cooking (Iacono et al. 1996). Excavation focused on the UaN Tomb I and associated burial pits and artifacts, as well as the human skeletal remains, most of which are disarticulated and fragmentary (Iacono et al. 1996).

Unar 1, consisting of a UaN tomb, is on the Shimal Plain in the Emirate of Ras al-Khaimah. Unar 2, the largest tomb yet discovered on the Arabian Peninsula (Blau 2001b), is located just south of Unar 1. Mowaihat is located seven kilometers inland from the present shoreline, between Ajman and Sharjah (al-Tikriti 1989).

The site of Tell Abraq is on the west coast of the Oman Peninsula, between Umm al-Qiwain and Sharjah. Unlike Unar 1, Unar 2, and Mowaihat, which have no known associated settlements, Tell Abraq exhibits a continuous sequence of occupation from the mid fifth millennium to the mid third millennium BP (Potts 1993c: 591). It was a large fortified settlement with a communal tomb and was based on intensified agriculture (Potts 1990b, 1993b).

The Wadi Suq Period (Fourth Millennium BP)

In the following Wadi Suq period, settlements became smaller and less permanent as a result of progressive desiccation and changes in copper trading, in addition to a decline in agriculture (Carter 1997; Crawford 1998). Patterns of health also changed. Grinding stones continued to be used at that time (Blau 1996), but domesticates were partly displaced by increased shellfish consumption (Grupe and Schutkowski 1989).

The Wadi Suq skeletal population, comprising largely disarticulated skeletons, was found at two sites: Sh. 602 on the Shimal Plain, in the Emirate of Ras al-Khaimah; and Sharm, approximately seventeen kilometers south of Dibba on the east coast of the UAE (Barker 1997).

The Iron Age (Late Fourth–Mid Third Millennium BP)

The Iron Age is characterized by a relatively homogeneous culture and marked by technological innovations including aqueducts and wells (*falaj*) (Potts 1990a), permitting settlement to flourish throughout the Oman Peninsula in all environmental zones (Potts 1990a). Domesticated camel provided both food and long-distance transport.

Evidence from Iron I and Iron II period sites suggests the diet contained

both marine and terrestrial foodstuffs, including barley, wheat, and dates (Potts 1997; Magee 1996b). The dental samples come from three sites: Wa'ab, located in the Emirate of Ras al-Khaimah; Naslah, in the Wadi al-Qawr; and Fashgha, also located in Wadi al-Qawr. The sites produced mostly fragmentary and/or disarticulated remains. No associated settlements were located for these tombs.

The Late Pre-Islamic Period (Late Third–Early Second Millennium BP)

It seems unlikely that the coastal regions were completely abandoned in the Late Pre-Islamic Period, but there is no evidence of settlement on either coast dating to the late third millennium BP (Potts 1998b: 44). By the early second millennium BP, the coast had again become occupied. Tell Abraq and other major sites were abandoned, but large trading settlements such as Mleiha (Hellyer 1998: 105) were established. One of the largest of these sites is Ed Dur, where fish and shellfish—including deep-sea varieties—made up most of the diet. Dates and domestic animals remained part of the diet (Potts 1998b).

Dental samples come from Ed Dur on the west coast of the UAE, one kilometer south of the bay of Khor el-Baidha (Potts 1990a: 274; Stone 1996: 5). Ed Dur has produced a variety of settlement and burial structures (Potts 1990a: 276–288; Stone 1996: 14–21). Skeletal material has been recovered, as Ed Dur had a long history of occupation that reached its height during this period (Boucharlat et al. 1988; Potts 1998b).

Results

Data relating to trauma, congenital abnormalities, joint disease, infection, cribra orbitalia, neoplasms, and developmental irregularities are available only from sites dating to the fifth (Umm an-Nar) and fourth millennia BP (Wadi Suq). These results have been reported using the standards of Buikstra and Ubelaker (1994) and Blau (2001a) and are briefly summarized in Table 13.2. Data on periodontal and dental disease—attrition, caries, enamel hypoplasia, calculus, antemortem tooth loss, and dental abscesses—for all periods are reported here for the first time.

TRAUMA

Evidence of trauma occurred at all fifth- and fourth-millennium sites with no distinct pattern, but it was generally more common at Umm an-Nar (UaN) sites than in the later Wadi Suq period (Table 13.2). Vertebral compression fractures were recorded only at UaN sites of the fifth millennium BP. Among UaN sites, Mowaihat displays the highest percentages of fractures of different

Table 13.2. Prevalence of Skeletal Alterations from Each Site

	Al-Sufūh							
Disease/ Alteration	Tomb 1	Tomb 2	Tomb 3	Tomb 4	Mowaihat	Unar 2	Sh. 602	Sharm
Postcranial skeletal elements	(*n*=1,245)	(*n*=3,767)	(*n*=3,245)	(*n*=52)	(*n*=3,307)	(*n*=12,982)	(*n*=700)	(*n*=2,989)
Trauma	0	0.3	0.4	0	1.0	0.5	0.7	0.07
Congenital	0	0.03	0	0	0.03	0	0	0
Joint	0.2	1.4	2.3	0	3.4	0.4	1	0.1
Nonspecific infect.	0	0.05	0.03	0	0.6	0.04	0	0.03
Neoplastic	0	0	0.03	0	0	0	0	0
Cranial skeletal elements[a]	(*n*=4)	(*n*=41)	(*n*=33)	(*n*=0)	(*n*=11)	(*n*=189)	(*n*=2)	(*n*=56)
Cribra orbitalia	25.0	41.5	33.3	0	27.3	17.5	50.0	40.0

Note: Data indicate percentage of skeletal elements affected.

[a] Sample size refers to frontal bones with intact orbits.

elements. Despite the round fortified towers of the Umm an-Nar period, UaN sites display no evidence of violent trauma.

JOINT DISEASE

Elements exhibiting alterations to the joints were recorded at all sites (with the exception of Sharm, of the Wadi Suq period) from the fifth and fourth millennia (Table 13.2). Eburnation was most common at al-Sufūh and Mowaihat (Umm an-Nar period), but most alterations were relatively minimal (grade 1 osteophytes or pitting). Vertebrae from Mowaihat showed alterations (osteophytes, grooving, and fusion of two upper thoracic vertebrae) not found at the other sites. The forearm, shoulder, foot, and pelvic area were particularly affected; the bodies of vertebrae were the most affected. At all sites, osteophytes (primarily grade one) were more common on lumbar vertebrae than on cervical or thoracic vertebrae. The absence of articulated skeletons prevents evaluation of the effects of ages at death on these patterns, but people at Mowaihat may have led more physically stressful lives.

INFECTION

In the absence of articulated skeletons, no specific infectious disease could be identified. Some long bones displayed possible infection in the form of periostitis or pitting. Infection was more common at Umm an-Nar sites than at those of the later Wadi Suq period (Table 13.2).

CRIBRA ORBITALIA

Examples of various stages of cribra orbitalia were observed at all sites dating to the fifth and fourth millennia BP. Although samples are small, this condition appears to have been less common at Umm an-Nar sites than at later Wadi Suq sites. Thalassemia and sickle-cell anemia are present in the UAE today (Blau 1998: 37–39), but iron-poor diets or parasites seem a better explanation for the relatively high incidence of cribra orbitalia (Shawky and el Din 1982).

DENTAL WEAR

A score for dental wear was recorded for each tooth. Incisors, canines, and premolars were given a score between one (minimal) and eight (extreme) wear. For molars, each of the four cusps was given a score between zero (no wear) and eight (extreme wear). The final score for each tooth (0–32) was the sum of the scores of the four quadrants (Figures 13.1 and 13.2). No significant differences in wear were found either between teeth or between sites.

Because of the lack of articulated skeletons, it is difficult to separate age at death from diet or other uses of dentition as factors in wear, but heavy wear

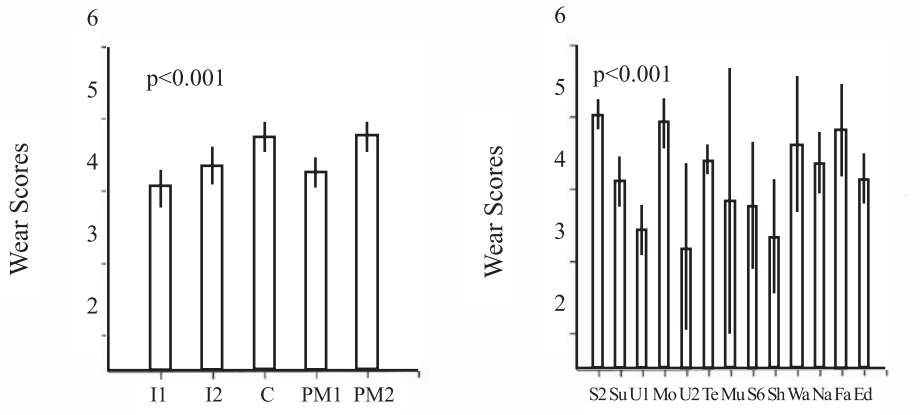

Figure 13.1. Difference in wear on anterior teeth from different sites in the United Arab Emirates.

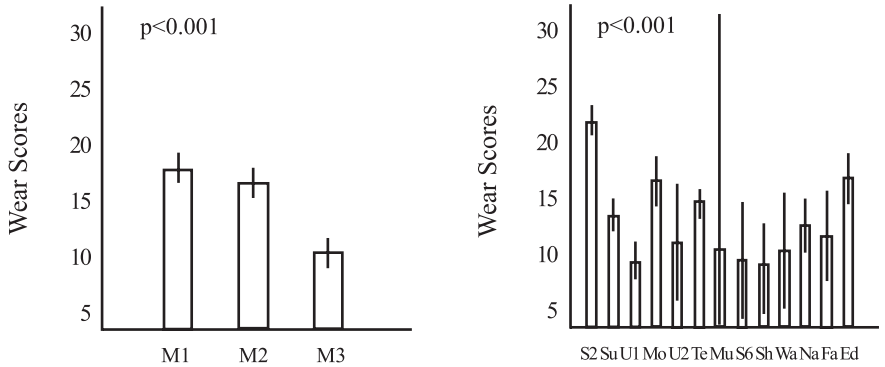

Figure 13.2. Difference in wear on molar teeth from different sites in the United Arab Emirates.

among some young individuals suggests that extreme wear cannot be attributed to age alone (see, for example, Blau 2001c).

The heaviest wear was found on teeth from Ubaid period Site 2 and contemporary sites around the Arabian Gulf (Coppa et al. 1985; Macchiarelli 1989; H. Kiesewetter pers. comm.). Teeth from fifth-millennium BP UaN sites displayed different patterns of wear. Although molars at these sites displayed extreme wear (occlusal surfaces flattened), most anterior teeth had only moderate dental wear (a distinct line of dentine was apparent).

Table 13.3. Scores Used to Record Position of Caries

Score	Position
1	Occlusal Surface
2	Interproximal Surface
3	Buccal/Lingual
4	Cervical
5	Root
6	Large[a]

Source: After Buikstra and Ubelaker 1994: 55.
[a] So much of tooth is destroyed that precise location is unclear.

Molar wear on teeth from the fourth millennium BP was moderate compared to that of teeth from earlier UaN sites, and there tended to be less difference in wear between molars than in the earlier sites. As at Wadi Suq sites reported elsewhere, anterior teeth showed relatively heavier attrition. During the Iron Age, tooth wear appears to have become less extreme (Kunter 1981, 1983).

CARIES

Rates of caries (see Table 13.3 for position scores) are very low in Ubaid period Site 2 (with an average of 0.4 percent) and at contemporary sites elsewhere (e.g. Coppa et al. 1985). Rates of caries are generally higher in UaN period sites (Figure 13.3), although frequencies are low at al-Sufūh and Mowaihat and somewhat low at Unar 1. Frequencies in the range of 8 percent were recorded at Unar 2 (n=55) and Tell Abraq (n=628).

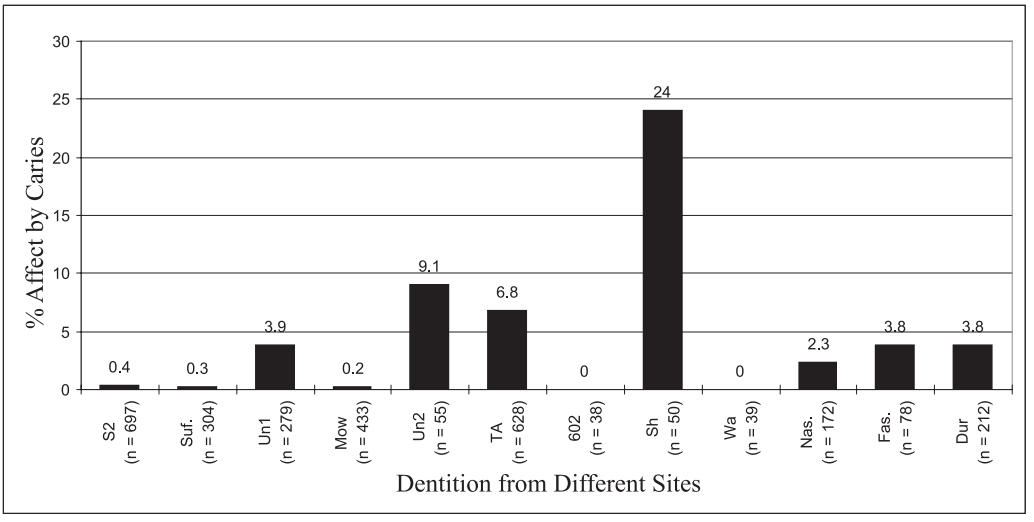

Figure 13.3. Prevalence of caries at each site in the United Arab Emirates.

For the Wadi Suq period, caries rates are highest at Sharm, affecting 24 percent of teeth (n=50), but no teeth from Sh. 602 (n=38) displayed caries. Information published elsewhere for teeth from sites dating to the fourth millennium BP generally suggests very low caries rates (Vogt et al. 1989; Hummel 1988).

The frequency of caries seems to have increased in the Iron Age, particularly at Naslah and Fashgha. However, Iron Age Wa'ab (n=39) displayed low rates. The prevalence of caries seen at Naslah and Fashgha is similar to results from other Iron Age sites, such as Ghalilah Site 2, reported elsewhere (Wells 1984: 271).

The frequency of caries at some Late Pre-Islamic sites remains at Iron Age levels (for example, Wells 1984). Other sites display much higher frequencies (Wells 1985).

The frequency of observed caries may, of course, be related to the degree of tooth wear at any site, because the percentage of caries decreases as the amount of wear increases. Gritty food helps in removing "cariogenic" food particles (Powell 1985: 332). Declining tooth wear during the sixth millennium BP may account for the generally increasing prevalence of caries through time.

ENAMEL HYPOPLASIA

Hypoplastic lines were measured using published methods (Buikstra and Ubelaker 1994). Intact dentitions were rarely recovered, so results were reported on the basis of total teeth affected as a percentage of teeth observed. All tooth classes were affected, the canines (19.7 percent, n=386) being most often affected.

Dentition from all sites except small samples from Iron Age Fashgha and Wa'ab (Figure 13.4) showed signs of enamel hypoplasia (EH), but nothing is known about rates of other pathologies at these sites. The highest prevalence rate of EH was observed at Mowaihat, where 12.3 percent of teeth (n=433) were affected by EH. Frequencies at this UaN site are significantly higher (p<.001) than at the other UaN sites, for which rates are low in comparison to those of the following period. The frequency at Tell Abraq is relatively low; the lowest prevalence rates for the Umm an-Nar period occur at Unar 2 (3.8 percent, n=53), al-Sufūh (3.3 percent, n=304), and Unar 1 (1.8 percent, n=279).

EH increased in frequency at the Wadi Suq period sites, Sharm and Sh. 602. Of particular interest is the fact that the prevalence of this enamel defect at Wadi Suq sites is similar to that at sites of other periods that displayed a similar dependence on marine resources.

ANTEMORTEM TOOTH LOSS

Antemortem tooth loss (AMTL) was measured as the ratio of teeth lost antemortem to those in situ or lost postmortem. The absence of age controls

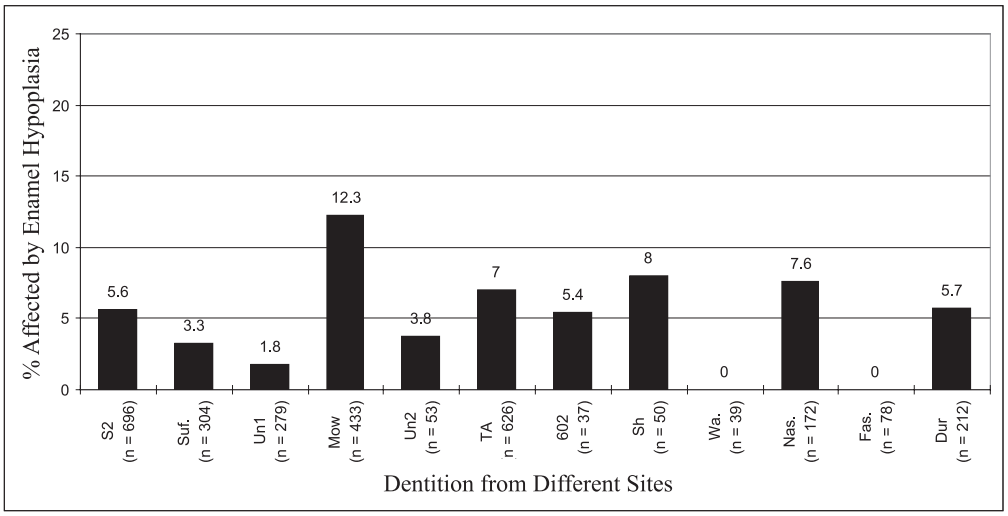

Figure 13.4. Prevalence of enamel hypoplasia at each site in the United Arab Emirates.

makes observed patterns difficult to interpret. AMTL was recorded at every site (Figure 13.5). Only Site 2, al-Sufūh, Mowaihat, Unar 1, Unar 2, Tell Abraq, Sh. 602 and Sharm were included in the statistical analysis because of the lack of maxillae in the Iron Age and Late Pre-Islamic samples. Mandibular teeth from these sites were significantly more affected than maxillary teeth.

AMTL is comparatively rare in Ubaid period Site 2, affecting only 12 percent of mandibles (n=25) and no adult maxillae (n=22). Low frequencies are also reported at contemporary sites elsewhere (Macchiarelli 1989: 583). A major increase in AMTL in mandibular teeth occurred in fifth-millennium BP UaN sites, which had dentition significantly more affected by AMTL than that of either the earlier (Ubaid) sites and similar to that of the later (Wadi Suq) sites. However, no temporal differences were found for the maxillae. The increase in caries at sites dating to the fifth millennium BP probably accounts for the obvious increase in AMTL. Rates of AMTL for other Wadi Suq sites, less fully reported, range from 15.8 percent to 35 percent (Hummel 1988: 3; Wells 1984: 216). The frequencies of AMTL at Ed Dur are comparable to those from the Umm an-Nar period but are far lower than those of other Late Pre-Islamic sites. For example, teeth had been lost from 35.3 percent of mandibular alveoli (n=34) from Site 3 (Wells 1984: 278). Similar results are reported from Site 5 (34.9 percent of 86 mandibular alveoli) (Wells 1985).

DENTAL ABSCESSES

Dental abscesses were recorded at only seven of the twelve sites discussed (Figure 13.6). In the majority of cases, mandibles were more affected than maxillae.

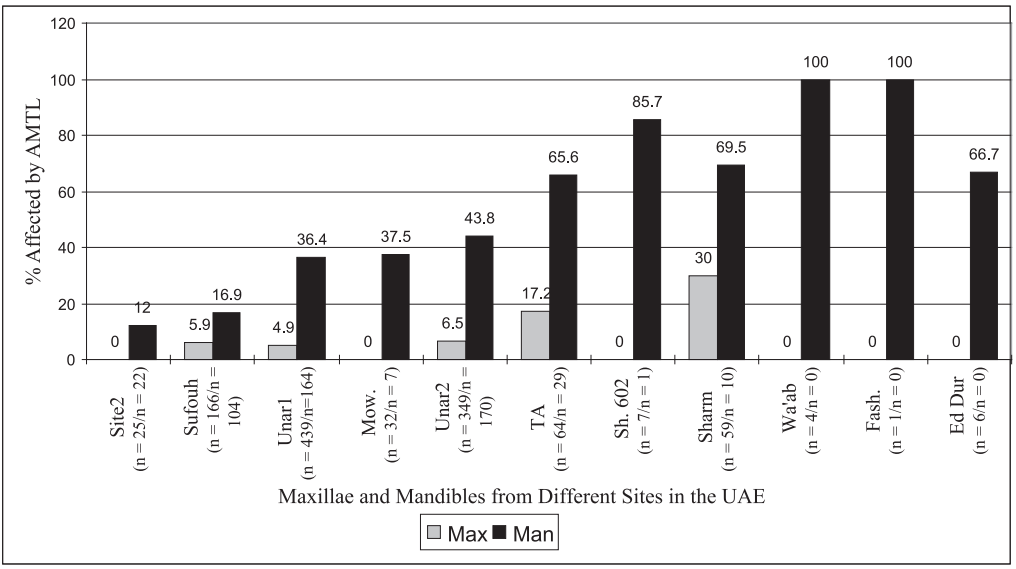

Figure 13.5. Percentage of dentition lost antemortem at each site in the United Arab Emirates.

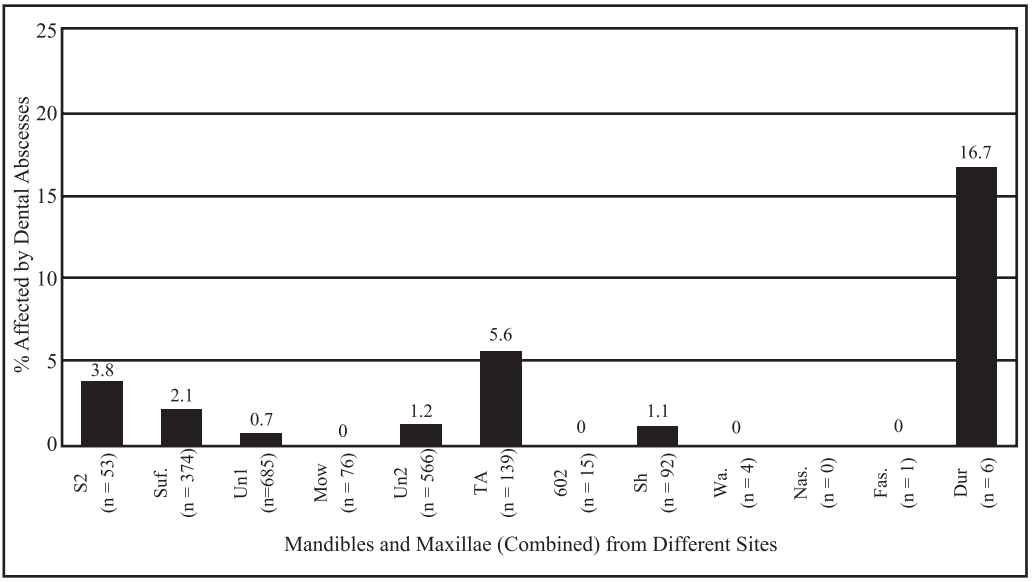

Figure 13.6. Prevalence of dental abscesses at each site in the United Arab Emirates.

Table 13.4. Scores Used to Record Degree of Dental Calculus Formation

Score	Degree
1	Small
2	Moderate
3	Large

Source: After Brothwell 1972: 150.

At most sites, there is a decline in the frequency of dental abscesses from the Ubaid period to the Iron Age. There is a dramatic increase in frequency during the Late Pre-Islamic period, a result probably skewed by small samples. The increase in AMTL through the sequence may explain the temporal decline in frequency of dental abscesses.

CALCULUS

Evidence of calculus (see Table 13.4) was found at all sites except Iron Age Wa'ab (Figure 13.7) and in all tooth classes. Mandibular incisors were significantly more affected than maxillary ones (p=.02). The highest prevalence rate of calculus (14.6 percent) was found at Ubaid period Site 2 (n=696) and UaN period Tell Abraq (n=628). The frequency of calculus at Tell Abraq was also significantly higher (p<.001) than at the other sites dating to the fifth millennium BP. In the Iron Age, the frequency of calculus decreases.

Discussion

THE UBAID PERIOD (LATE SEVENTH/EARLY SIXTH MILLENNIUM BP)

The Ubaid period is characterized by seasonal coastal and inland camps with pottery. The mixed economy included marine resources, as well as cattle, sheep, and goat.

Extreme dental wear probably reflects dietary dependence on gritty marine food as well as meat and bones (Macchiarelli 1989; Littleton and Frohlich 1989), in addition to dried fish and crabs, inadequate food preparation, and incorporation of particles of sand and ash during cooking (Townsend et al. 1994). As a result of high reliance on marine foodstuffs and the scarcity of foods high in sugar, there is little evidence for other oral diseases.

THE UMM AN-NAR PERIOD (FIFTH MILLENNIUM BP)

Monumental building during the Umm an-Nar period involving heavy strenuous labor may explain the occurrence of vertebral compression fractures, Schmorl's nodes, and spondylolysis at fifth-millennium BP sites (see, for ex-

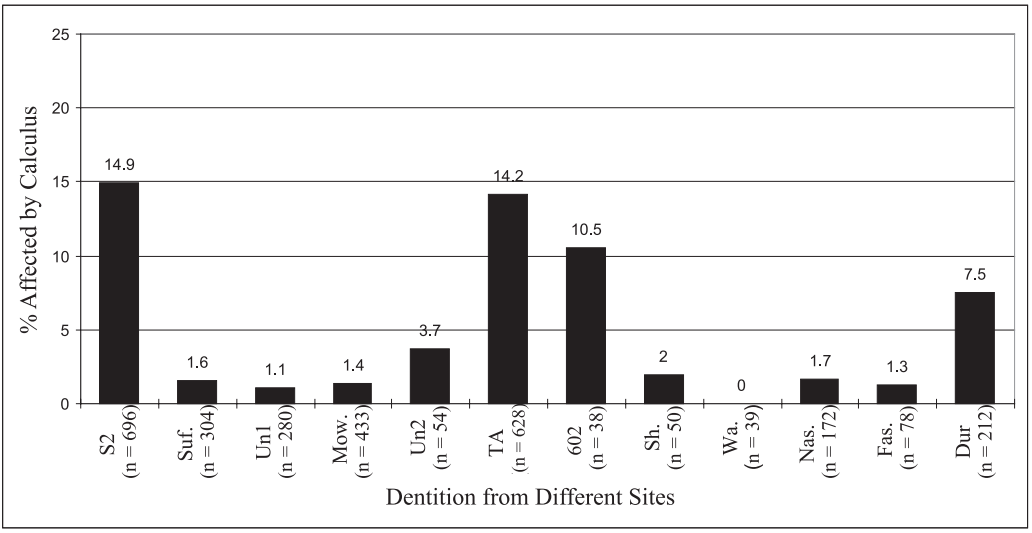

Figure 13.7. Prevalence of calculus at each site in the United Arab Emirates.

ample, Potts 1997). Compression fractures may also represent age-related conditions such as osteoporosis, perhaps suggesting that people were living longer. Without entire skeletons, however, the effects of age cannot be separated from those of labor.

The permanent nature of the UaN sites, greater nucleation of settlements, large-scale construction, and possible hierarchical organization may explain the higher rates of infection and cribra orbitalia at these sites than at smaller and less permanent later sites. The co-occurrence of high rates of nonspecific infection and cribra orbitalia may suggest that parasites and infection helped reduce the availability of iron.

Alterations in tooth wear and increased caries rates in the Umm an-Nar period are probably related to the inclusion of new sources of carbohydrates: wheat, barley, and the date palm (Wilcox and Tengberg 1995; Potts 1997). However, the frequency of caries at al-Sufūh and Mowaihat remains low, comparable with the frequency for the earlier Site 2, as is the case with Umm an-Nar Island and Tomb A, Hili North (Højgaard 1980; El-Najjar 1985).

The use of grinding stones—introducing grit to the diet—may have contributed to dental attrition, which, although not as extreme as that seen in the Ubaid period, remained prominent (Blau 1996).

Assessment of the dentition suggests that compared to that of other Umm an-Nar sites, dental health at Tell Abraq was relatively poor; the frequency of nearly all oral pathologies is higher at this site. The general decline in the occurrence of calculus on teeth (except at Tell Abraq) may indicate improved oral

hygiene. However, teeth are better preserved at Tell Abraq, which may account for the difference in this and other oral pathologies between Tell Abraq and other fifth-millennium BP settlements. It is interesting to note that increased calculus deposits at Tell Abraq (compared to other contemporary sites) are associated with increases in reliance on agricultural products (Littleton and Frohlich 1989). Furthermore, the frequency of caries at Tell Abraq is in the range considered typical of agricultural groups, while that of Unar 1 is more akin to the range characterized by mixed subsistence. The fact that the frequency of caries at al-Sufūh and Mowaihat is startlingly lower than those at other sites may reflect geography and chronology. The location of al-Sufūh and Mowaihat on the southern part of the coast may account for their weak trade connections (as shown by the differences in compositional analyses of bronze tools from al-Sufūh; L. Weeks pers. comm.). Thus, despite homogeneity in material culture over a very wide geographical area during the Umm an-Nar period (Tosi 1975), access to food resources may have been more hierarchical than it was during other periods.

The Wadi Suq Period (Fourth Millennium BP)

The Wadi Suq period saw the general decline of large and permanent settlements and burials. Such alterations in settlement (and possibly population) size appear to have had an impact on the types of diseases that affected the population. With the exception of cribra orbitalia, frequencies of spinal trauma, arthritis, and infection all seem to have declined from the earlier period.

However, hypoplasia increases in frequency at Wadi Suq sites. This may reflect a shift in diet at this time, with an increased dependency on marine foods making the obtaining of complete nutrition more difficult.

High frequencies of tooth loss have been explained by some investigators as resulting from heavy carious infection (Vogt et al. 1989: 66; Schutkowski and Herrmann 1987: 62). It may be possible to attribute the increase in AMTL in Wadi Suq sites to caries. But given the generally low frequency of caries at sites of this period with Sharm's 24 percent being the exception, dental abscesses may also have been a contributing factor.

The Iron Age (Third Millennium BP)

The Iron Age is characterized by the first use of a new water-exploitation technology (the *falaj*), enabling agriculture to be practiced and permanent settlements to expand throughout the Oman Peninsula. There are no studies of general health indicators for this period. Although detailed information about dental health during the Iron Age is sparse, some differences from and similarities with the preceding periods were observed. Increased rates of dental caries probably reflect the new water technology and increased consumption

of dates. Dental wear is still only moderate, compared to that of the Wadi Suq period, and is only slight on the anterior teeth (Kunter 1981: 207, 1983: 339).

In general, frequencies of enamel hypoplasia from Iron Age sites remain the same as those of the Wadi Suq period, while the frequencies of calculus decrease. With the exception of Sharm, the frequency of caries increase.

The Late Pre-Islamic Period (Late Third–Early Second Millennium BP)

The Late Pre-Islamic period saw the establishment of large occupation sites and trade networks. The diet consisted of a wide variety of foods including both marine and terrestrial fauna and dates.

Information on general skeletal pathology is not yet available for the pre-Islamic period, and dental remains from the Late Pre-Islamic period are sparse. Material from only one site (Ed Dur) suggests that dental health altered only slightly between the Iron Age and the Late Pre-Islamic period. Frequencies of dental calculus and enamel pitting slightly increase but are significantly lower ($p<.001$) than frequencies seen during the Umm an-Nar period. The frequency of caries remains roughly the same as that in the Iron Age. Similar frequencies of caries were observed at other Late Pre-Islamic sites (Wells 1984: 278).

Conclusions

Despite poor preservation and disarticulated skeletons, it has been possible to observe trends in the prevalence of different types of pathology. The alterations in the prevalence of oral pathologies have been attributed to shifts in diet, which parallel archaeological evidence for changes in settlement patterns and associated exploitation of resources. Certain conclusions can be reached in regard to the comparison of skeletal elements analyzed in this study.

1. Many dental problems fluctuate in frequency as much among sites as between periods and can only be summarized easily in tables. But in general, wear, abscesses, and calculus generally decline through time whereas caries and AMTL generally increase.
2. Where postcranial skeletons and whole skulls can be observed, there is little if any evidence of violent trauma in the sequence, even in the Umm an-Nar period (when fortifications are noted).
3. There is some tendency for linear enamel hypoplasias to be higher in later parts of the sequence, but they appear to correlate not with dependence on farming or political complexity but with reliance on seafood.
4. Rates of trauma, infection, and cribra orbitalia all appear to peak in the Umm an-Nar period in association with evidence of relatively large set-

tlements, monumental construction, fort-like structures, and evidence of social stratification. By contrast, enamel hypoplasia increases in the later period.

Acknowledgments

I am grateful to the directors of archaeology in the Dubai Museum and the National Museum of Ras al-Khaimah (UAE), as well as to Carl Phillips, Ross Cunningham, Christine Donnelly, Tim Denham, and Renata Henneberg.

14

Ancestors and Inheritors

A Bioanthropological Perspective on the Transition to Agropastoralism in the Southern Levant

PATRICIA SMITH AND LIORA KOLSKA HORWITZ

Between 13,000 BP and 7500 BP, human populations in the Near East shifted from an extractive mode of production, founded on hunting and gathering, to an economy based on primary production through domestication of plants and animals (Bar-Yosef and Meadow 1995; Bar-Yosef 1998; Bar-Yosef and Belfer-Cohen 1999; Belfer-Cohen and Bar-Yosef 2000; Kuijt and Goring-Morris 2002). The Southern Levant provides one of the most detailed records of this process. Located south of the nuclear zone of domestication now identified in the Levant (Peters et al. 1999; Lev-Yadun et al. 2000), the transition to agropastoralism in the Southern Levant took some 5,500 years, within which a number of distinctive stages can be identified. The earliest is the Natufian period, associated with intensified resource exploitation through hunting and gathering, increased site size and sedentism. It was followed by the Pre-Pottery Neolithic (PPN), characterized by domestication of plants (cereals and legumes) accompanied over the next 1,000 years by domestication of herd animals (goats, sheep, pigs, cattle). The PPN was associated with augmented site, population size and density, as well as increased sedentism and social complexity. Identification of the different stages of "Neolithization" provides an excellent opportunity to assess the impact of changing adaptations on health status during this important phase of human development.

Skeletal Samples

Skeletal remains of more than six hundred individuals have been recovered from well-dated sites covering all phases of this transition (Figure 14.1). However, the majority of specimens are so fragmentary that less than half can be accurately aged or sexed. As can be seen in Figure 14.2, the age distribution of samples varies between sites and reflects differential burial patterns and diagenetic processes rather than age at death of any particular group. This is attested to by the abnormally low ratio of infants to children, while at some sites pre-

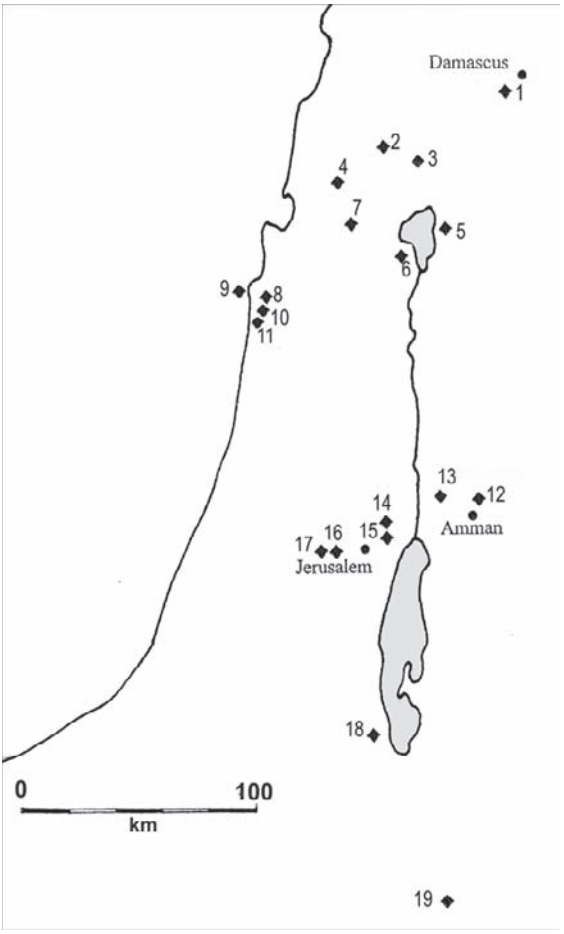

Figure 14.1. Map of the Southern Levant showing the distribution of sites: *1*, Tell Ramad; *2*, Eynan; *3*, Beisamoun; *4*, Hayonim; *5*, Ein Gev; *6*, Ohalo; *7*, Kfar Hahoresh; *8*, Nahal Oren; *9*, Atlit Yam; *10*, El Wad; *11*, Kebara; *12*, {ay}Ain Ghazal; *13*, Wadi Shuíeib; *14*, Netiv Hagdud; *15*, Jericho; *16*, Abu Ghosh; *17*, Hatoula; *18*, Nahal Hemar; *19*, Basta.

dominantly adults are present. This means that pooling samples from different sites and phases within the Natufian and Neolithic for paleodemographic analysis (Hershkovitz and Gopher 1990; Eshed et al. 2004a) compounds the errors inherent in the use of small samples.

The small sample sizes also affect the validity of morphometric analyses, since they do not encompass the full range of variation found in the parent populations. To assess the reliability of the values obtained from our small data set, we focused on sites with the largest and best-documented samples. Furthermore, we adopted data obtained from a recent North African isolate (Briggs and Guede 1964) to provide a standard against which to assess the extent to which the range of variation observed in our samples conforms to that expected in small homogeneous groups (Figure 14.3).

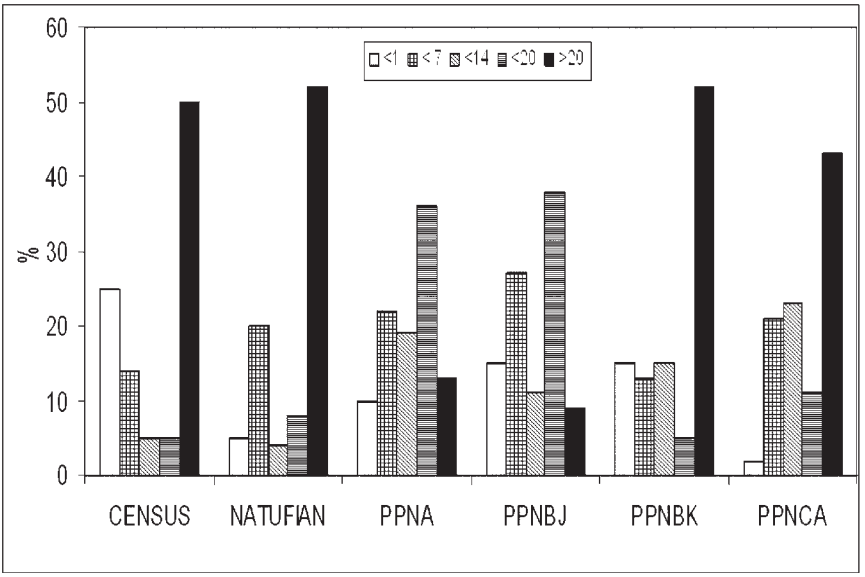

Figure 14.2. Age distribution (in years) from sites in the Southern Levant. Number of individuals: Census, 4,982; Natufian, 82; PPNA, 276; PPNBJ, 212; PPNBK, 40; PPNCA, 47. Note that the frequency of infants and children in all archaeological sites is low compared to that of nineteenth century census data that is based on birth and death registration. Either infants were not buried on site or their bones were not preserved.

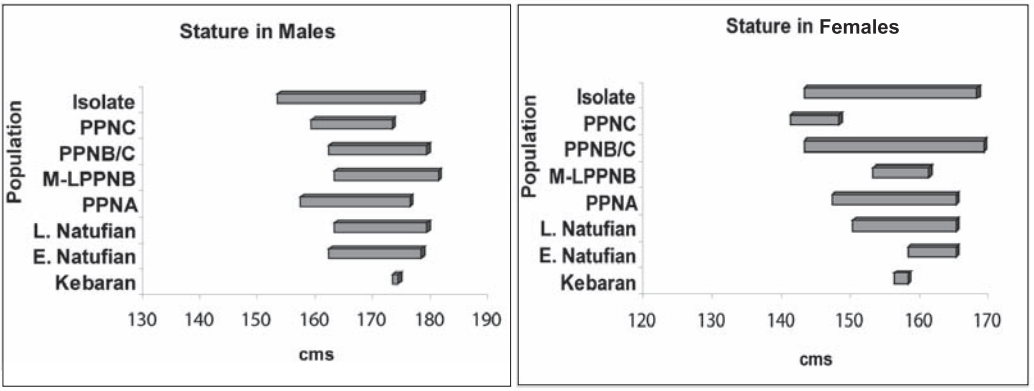

Figure 14.3. Stature in males (left) and females (right) from the Southern Levant. Note the markedly shorter female stature in the PPNC. The expected variation in stature based on the isolate is ca. 25 cms, but for most periods represented, the range is smaller because of small sample sizes and does not fully represent the parent population.

Natufian Period

The Natufians are considered to have initiated the lifestyle that culminated in agropastoralism (Bar-Yosef 1998). Three phases have been identified in this period: Early (13,000–11,000 BP), Late (11,000–10,500 BP), and Final (circa 10,500–10,300 BP). Early Natufian sites are larger than those of the preceding Kebaran period, and social organization was probably more complex. In the Early Natufian, some living sites may have been occupied year-round; all show increased reliance on small-game and plant resources, especially cereals, compared to the subsistence regime of the preceding Kebaran period. The Late and Final Natufian are characterized by a reduction in the size and duration of site occupation and a return to a more mobile lifestyle associated with expansion into previously unoccupied marginal areas. Domestic dogs made their appearance at this time, antedating other domesticates by more than a millennium (Belfer-Cohen 1991; Belfer-Cohen et al. 1991; Bar-Yosef and Belfer-Cohen 1992; Valla 1995; Tchernov and Valla 1997; Bar-Yosef 1998; Stiner and Monroe 2002).

The largest well-dated skeletal sample is that from Eynan, with 104 individuals spanning all phases of the Natufian (Bocquentin 2004). This averages out to one burial per century, emphasizing the problem of paleodemographic reconstruction from such chronologically disparate samples. The data that are available indicate that few survived beyond the age of 45 years. There are, however, relatively more old adults in the Early Natufian than in the Final Natufian (Bocquentin 2004). Despite their younger age at death, the Final Natufians have a higher incidence of cribra orbitalia and otitis media, suggesting some deterioration in health.

Early Natufian populations are less robust with smaller teeth than their Kebaran ancestors (Figure 14.4). Throughout the Natufian and succeeding Neolithic periods, craniofacial proportions vary as the jaws and teeth reduce in size attesting to changes in the physical composition of food (Figure 14.5). This is associated with an increased frequency of caries, attrition, and antemortem tooth loss indicative of an abrasive carbohydrate diet (Figure 14.6). The decreased facial robusticity and associated increase in dental disease provide independent evidence of the diachronic increase in consumption of processed cereals inferred from the archaeological record (Bocquentin 2004; Bocquentin et al. 2001; Belfer-Cohen et al. 1991; Smith 1972, 1991, 1995; Smith et al. 1984; Valla et al. 2001).

Belfer-Cohen and colleagues (1991) reported that mean stature and dimorphism decreased between the Early and Final Natufian, but sample sizes are small and examination of the range of variation provides no statistical evidence of change (Figure 14.3). There is little evidence of trauma in Natufians. A few

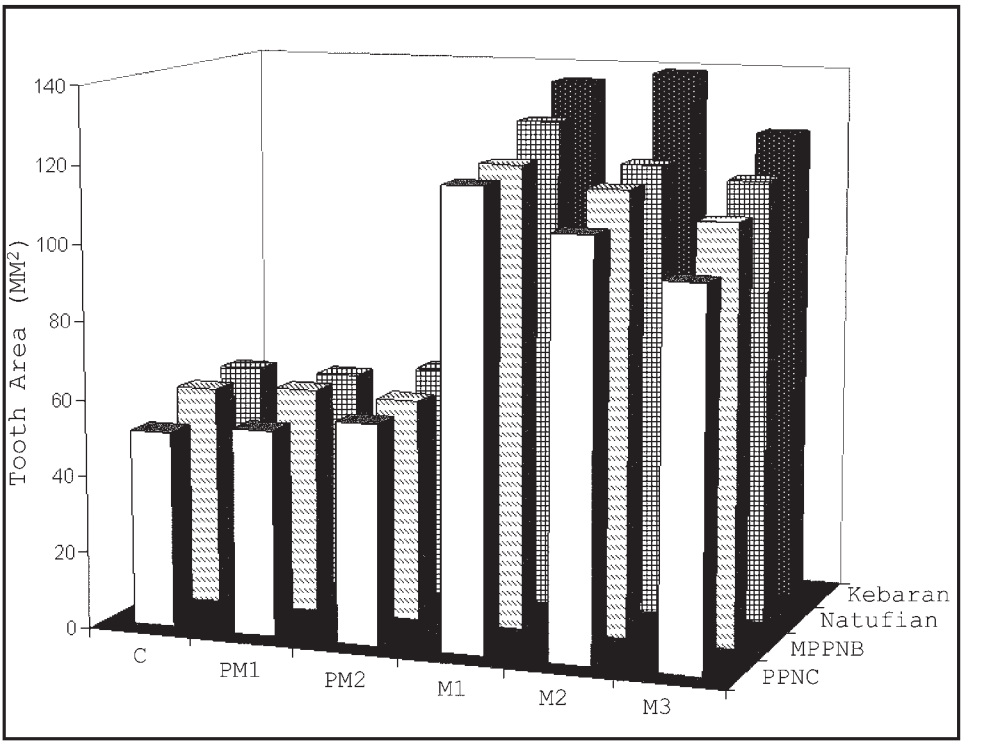

Figure 14.4. Mandibular tooth area by tooth type at sites in the Southern Levant (mesio-distal x bucco-lingual diameters in mm). Note the diachronic trend in diminution of tooth size. Teeth measured by P. Smith.

Figure 14.5. Change in the cranial form from Natufian (left) to PPNC (right) in the Southern Levant; the latter has a more rounded skull and smaller face and maxilla than the Natufian.

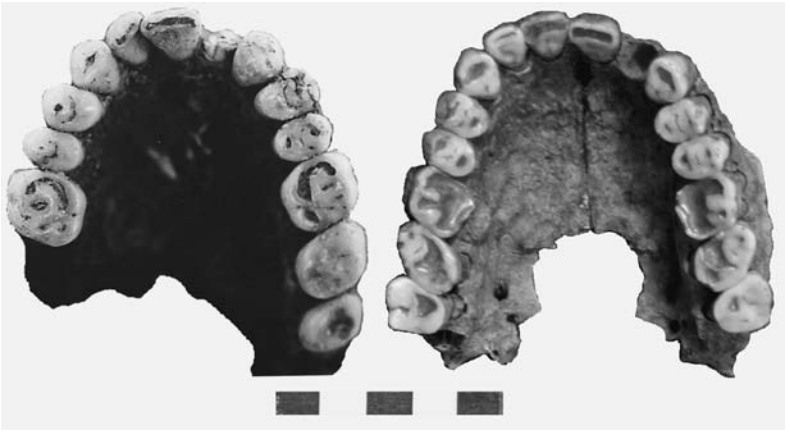

Figure 14.6. Occlusal views of maxillae from the Natufian site of El Wad (left) and the PPNC site of Atlit Yam (right), Southern Levant. Note the marked difference in severity of attrition between the first molar and other teeth in the Atlit Yam specimen.

Early Natufian skulls exhibit healed circumscribed depressions on the skull that have been interpreted as head wounds (Eshed 2001; Webb and Edwards 2002; Bocquentin 2004), but none appear to have resulted in severe disability or death.

Pre-Pottery Neolithic Period

The gradual adoption of agropastoralism can be traced through the successive stages of the Pre-Pottery Neolithic period: Pre-Pottery Neolithic A (PPNA 10,300–9600 BP) and Pre-Pottery Neolithic B (PPNB 9600–7500 BP), in which there are four subphases.

THE PRE-POTTERY NEOLITHIC A

The PPNA shows considerable continuity with the Late/Final Natufian in subsistence, technology, and material culture (Belfer-Cohen and Goring-Morris 1996). However, plant remains as well as the increased frequency of silos and ground stone tools used for milling demonstrate greater dependency on, or even incipient cultivation of, wild cereals and legumes (Wright 2000; Colledge et al. 2004). This subsistence shift may explain why some sites, such as Jericho, show a marked increase in size, complexity, and permanence (Kuijt and Goring-Morris 2002).

The largest skeletal sample is from Jericho, with 262 individuals derived from this phase (Kurth and Röhrer-Ertl 1981). The PPNA skeletal sample studied in most detail is from Hatoula, although sample sizes are very small (Le

Mort et al. 1994; Smith and Verdene 1994). At a third PPNA site, Netiv Hagdud, preservation was too poor to permit detailed analysis (Belfer-Cohen et al. 1990; Belfer-Cohen and Arensburg 1997).

Cranial measurements have been published for only three PPNA crania (one from Jericho and two from Hatoula), although long bone measurements and tooth size are available for slightly larger samples. The PPNA populations resemble those of the preceding Late and Final Natufian but show further reduction in craniofacial robusticity and tooth size (Kurth and Röhrer-Ertl 1981; Le Mort et al. 1994; Smith and Verdene 1994). Skeletal pathology and dental disease remain high in the PPNA. At Hatoula, four of the seven best-preserved adults exhibited arthritic lesions of vertebrae or foot bones. One had a healed fracture of the right arm, and another had multiple abscesses in the right mastoid region. Teeth and jaws from six of these specimens, together with isolated teeth and jaws of another four individuals, showed attrition exposing the pulp chamber in the molars. Three adults had caries with abscesses around the roots of the teeth. All individuals from Hatoula had one or more hypoplastic teeth (Smith and Verdene 1994). At Jericho, four adults exhibited fractures of long bones, and a 2-year-old child had a suspected case of rickets (Kurth and Röhrer-Ertl 1981). Stature estimates for females at Jericho (Kurth and Röhrer-Ertl 1981) are lower in the PPNA than in the subsequent PPNB; they are 147–165 cm in the PPNA compared to 153–161 cm in the PPNB (Figure 14.3), suggesting nutritional stress in childhood. This conclusion is reinforced by the high levels of dental hypoplasia at PPNA Hatoula. Although these data do not provide a quantitative estimate of disease frequency, they suggest that the poor health posited for the Late and Final Natufian was maintained into the PPNA.

THE PRE-POTTERY NEOLITHIC B

This period heralds a major break in lithic techno-typology, architecture, and ideology expressed in mortuary practices. It marks the widespread adoption of domestic plants and animals, although this process appears to have been staggered and geographically uneven. Four phases are recognized: Early (EPPNB), 9600–9300 BP; Middle (MPPNB), 9300–8500 BP; Late (LPPNB), 8500–8000 BP; and the Final, or Pre-Pottery Neolithic C (PPNC), 8000–7500 BP (Bar-Yosef and Belfer-Cohen 1992; Bar-Yosef and Meadow 1995; Goring-Morris and Belfer-Cohen 1998; Garrard 1999; Horwitz et al. 1999; Kuijt and Goring-Morris 2002).

The EPPNB is poorly known. Sites are small (up to two hectares), characterized by curvilinear and rectangular architecture with lime-plastered floors, while faunal remains point to a hunting-based economy (Bar-Yosef and Belfer-Cohen 1992; Horwitz et al. 1999; Kuijt and Goring-Morris 2002). To date, the

only published anthropological report is for the site of Horvat Galil, where four poorly preserved individuals were identified (Hershkovitz and Gopher 1988). They showed no distinguishing features to set them apart from the PPNA population.

MPPNB sites are larger (half a hectare to three hectares) and architecturally more complex than those of the PPNA and EPPNB, increasing to eight–twelve hectares in the LPPNB (that is, from approximately 800 to 3,300 people per site; Kuijt 2000). These data suggest that as early as the MPPNB, settlements supported larger numbers of people living under conditions of increased crowding. Mortuary practices are complex and include skull removal, decoration of skulls, and interment of animal remains, artifacts, ornaments, and statuettes, attesting to communal activities and a rich symbolic life (Bar-Yosef and Belfer-Cohen 1992; Kuijt and Goring-Morris 2002).

The MPPNB provides the earliest unequivocal evidence for domestic cereals and probably also legumes in the Southern Levant (Garrard 1999; Colledge et al. 2004). Toolkits are more varied than those previously found, while milling stones are more common and have wider grinding surfaces (Wright 2000). Storage facilities expanded from the MPPNB to the LPPNB, possibly indicating privatization of supplies and/or the increasing scale of surpluses (Kuijt and Goring-Morris 2002). A sudden increase in the frequency of goats exploited, coupled with a marked bias in their age and sex distribution, indicates that their management was underway by the MPPNB. However, the morphometric changes associated with domestic forms are first seen in the LPPNB, some five hundred years later. In the latter period, domestic sheep were introduced into the Southern Levant (Horwitz et al. 1999; Peters et al. 1999; Horwitz 2003). Domestic cattle are also present at this time, although it is still unclear if they were introduced or locally domesticated in this region (Horwitz and Ducos 2005). Domestic pigs are latest and are found by the Pottery Neolithic (Horwitz et al. 1999; Haber and Dayan 2004).

Human remains have been recovered from numerous MPPNB sites, but the majority are poorly preserved. The largest sample is again that from PPNB levels at Jericho with 212 individuals. The few human cranial measurements available from sites such as Tell Ramad (Ferembach 1969), Jericho (Strouhal 1974), Nahal Hemar (Arensburg and Hershkovitz 1988; Yakar and Hershkovitz 1988), and Abu Ghosh (Arensburg et al. 1978; Sklar-Parnes and Smith 2003) show considerable variation. They include some specimens with exceptionally broad crania and wide rami relative to those of the preceding periods. Average male stature at MPPNB Jericho is four centimeters greater than that of the PPNA at the same site; 167 cm in the PPNA compared to 171 cm in the PPNB (Kurth and Röhrer-Ertl 1981) (Figure 14.3), and similar to data for other MPPNB sites such as Abu Ghosh (Arensburg et al. 1978; Sklar-Parnes and

Smith 2003). The MPPNB specimens also show increased skeletal robusticity relative to the Natufian and PPNA but smaller teeth (Figure 14.4) (Arensburg et al. 1978; Soliveres 1978; Peterson 1997, 1998; Eshed et al. 2004b).

These skeletal changes were accompanied by decreased severity of skeletal pathology and hypoplastic defects of the teeth, but increased caries rates, severity of dental attrition, and frequency of antemortem tooth loss. At MPPNB Abu Ghosh, two of eleven adults had attrition exposing the pulp chambers of the molars, three had dental abscesses, and three suffered from antemortem tooth loss of first molars (Arensburg et al. 1978; Sklar-Parnes and Smith 2003). A similar picture is reported for coeval samples from ʿAin Ghazal (Sarie 1995) and Kfar Hahoresh (Eshed 2001; Eshed et al. 2006). However, because many specimens are known only from isolated dental remains and could not be accurately aged or sexed, the increase in dental pathology may signal the presence of a larger number of old individuals in the samples studied rather than a more abrasive and cariogenic diet.

Only two LPPNB skeletal samples have been published to date: Basta and Wadi Shuʾeib. Both are characterized by higher frequencies of dental pathology and skeletal lesions, indicative of infectious disease, than have been found for the MPPNB. Schultz (1987) and Schultz and Scherer (1991) reported that ten of thirty-five individuals from LPPNB Basta had endocranial lesions indicative of meningo-encephalitis, seven had osteomyelitis or periostitis of long bones, and there were three possible instances of scurvy. Trauma, expressed by healed depressed fractures of the skull, was evident in three out of twelve adult males. Arthritic lesions were common, especially in the shoulder and mandibular joints of older individuals. Severe dental disease was evident, with four out of five adults having carious teeth. All showed some degree of periodontal disease, and hypoplastic defects were present on the teeth of over 66 percent of the sample.

The small LPPNB dental sample from the site of Wadi Shuʾeib described by Al-Abbasi and Sarie (1997) reflects a similar poor standard of health. Hypoplastic defects were found in 72.7 percent of upper central incisors, indicating exposure to nutritional stress or infection in the first year of life. In contrast, hypoplastic defects in Natufian, PPNA, and MPPNB populations were most common in the cervical region of the canine that calcifies between 4 to 6 years of age. Although the pathologies evident in the LPPNB cannot be attributed to specific pathogens, skeletal findings demonstrate a higher disease load than has been reported for earlier populations.

The PPNC is characterized by a fully established agropastoral economy supplemented by hunting and gathering. During this period, many sites contracted into small hamlets or were abandoned, and people dispersed into new localities. These shifts have been attributed to climatic change, overexploita-

tion of local resources, and/or the collapse of social belief systems in the face of these new challenges (Rollefson and Köhler-Rollefson 1989; Rollefson et al. 1992; Rollefson 1996; Kuijt and Goring-Morris 2002).

PPNC skeletal samples have been recovered from the submerged site of Atlit Yam (Hershkovitz and Galili 1990) and from ʿAin Ghazal (Rollefson et al. 1985, 1992). A small sample of females was described by Hershkovitz and Galili (1990) as characterized by short stature; small, rounded crania; and short mandibles with broad ascending rami (Figure 14.5). Stature estimates for females include some of the shortest recorded for any of the periods studied here (approximately 143 centimeters), but male stature falls within the range of the relatively tall MPPNB population (Figure 14.3).

Eshed (2001) reported a fourfold increase in the frequency of infectious diseases relative to trauma between the Natufian and the Neolithic. When broken down by phase within the Neolithic, her data reveal few cases of infectious disease in the PPNA to MPPNB samples but many in the PPNC sample from Atlit Yam, in which eight individuals had cribra orbitalia compared to three from all PPNA and MPPNB samples combined. Specimens from PPNC ʿAin Ghazal also exhibited a high frequency of infectious lesions that included three possible cases of tuberculosis (El-Najjar et al. 1997), while at Atlit Yam two individuals exhibited skeletal changes attributed to alpha thalassemia, a mutation associated with endemic malaria (Hershkovitz et al. 1991).

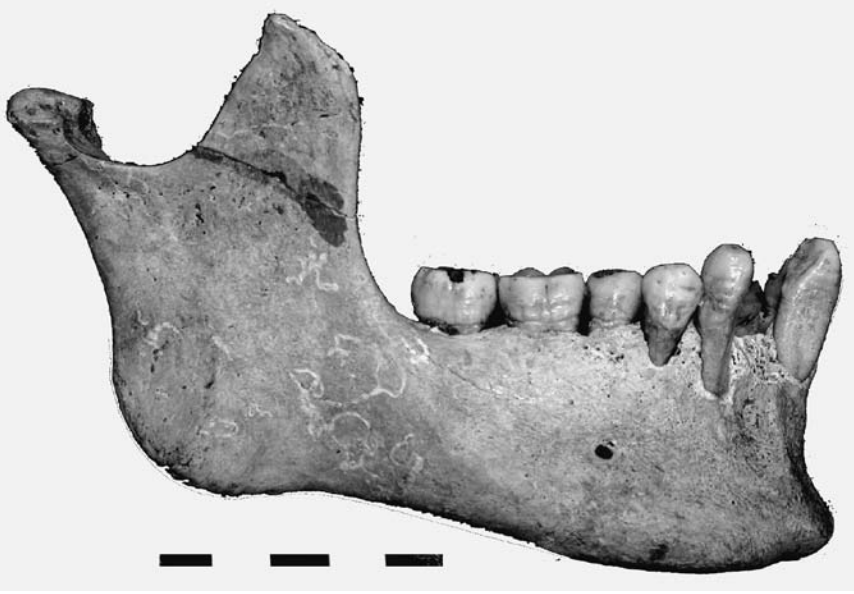

Figure 14.7a. Lateral view of mandible from the PPNC site of Atlit Yam, Southern Levant, showing hypoplastic defects in all permanent teeth.

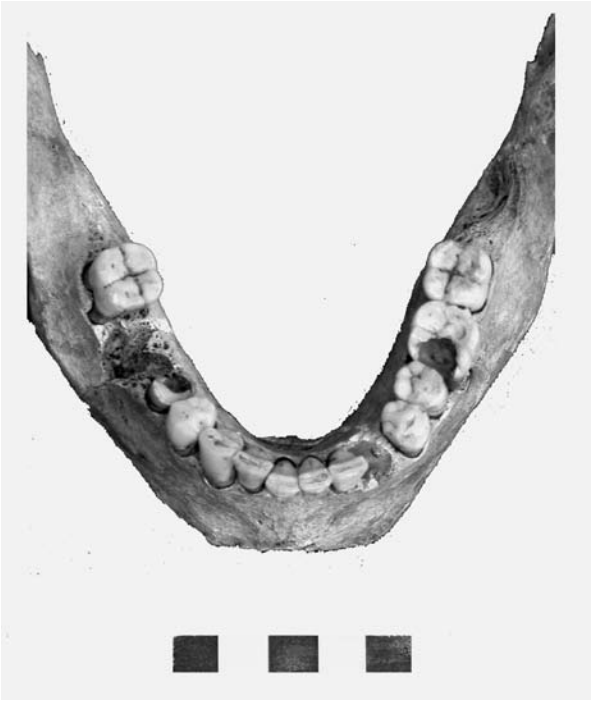

Figure 14.7b. Occlusal view of mandible from Atlit Yam, Southern Levant, showing large carious lesions.

The dental findings support the hypothesis of increased stress in the PPNC. All seventeen individuals from Atlit Yam with permanent teeth that were studied by us had hypoplastic enamel (Figure 14.7a). In many individuals, these defects affected incisors and first molars and extended over one-third to one-half of the crown, indicating exposure to stress in the first year of life. Moreover, in 36 percent of lower canines, the entire surface of the crown was hypoplastic, while 50 percent had hypoplastic defects extending over at least half the tooth surface, suggesting repeated or continuous chronic stress from infancy though early childhood. Only in the remaining 14 percent of lower canines were the hypoplastic defects limited to the cervical portion of the tooth. Thus, at Atlit Yam, we are confronted with evidence for developmental disturbances throughout the entire period of dental development, a finding that agrees well with that of Sarie (1995), who reported an increase in dental hypoplasia in early developing teeth at PPNC ʿAin Ghazal relative to those of the PPNB levels.

At Atlit Yam, antemortem tooth loss was found in five out of twelve adults. Since only two individuals showed exposure of secondary dentine in any tooth, whereas caries is present in three out of twelve adults (Figure 14.7b), some of the antemortem tooth loss was probably secondary to pulpal infection from caries. At the same time, dental attrition remained severe (Figure 14.6).

The evidence cited above attests to more severe dental disease and attrition in the PPNC than in preceding periods and confirms the archaeological evidence for increased dependency on processed cereals at this time. Both dental disease and attrition are age related, such that increased disease incidence associated with less attrition in the PPNC indicates dietary change rather than age differences at death.

Discussion

In this chapter, we have attempted to differentiate between the various factors influencing human ecology during the transition from hunting and gathering to agropastoralism in the Southern Levant. This process was characterized by staggered and gradual shifts in the intensity and manner in which people exploited plants and animals.

The skeletal remains of the populations undergoing this transition show that the trend towards skeletal gracilization and reduction in tooth size in the Southern Levant began in the Upper Paleolithic, long before the adoption of agriculture, and accelerated between the Early Natufian and the PPNC (Smith 1995). However, in contrast to tooth size, skeletal robusticity does not show a monotonic change but undergoes a temporary reverse in the MPPNB, decreasing again thereafter. Unfortunately, the fragmentary condition of most of the specimens means that few quantitative analyses have been carried out, but the general trend is clear.

The data presented in this chapter demonstrate the existence of two major low points in health status. The first took place during the Late/Final Natufian–PPNA, while the second occurred in the LPPNB–PPNC. Both instances are characterized by environmental deterioration and the onset of more-arid climatic conditions that were associated with changes in patterns of human settlement (Goring-Morris and Belfer-Cohen 1998).

The poor health inferred for the Late/Final Natufian–PPNA populations coincides with the critical transition from foraging to incipient agriculture. This time span covers more than one thousand years and is best perceived as a long-term trend rather than a short-term crisis. The skeletal and archaeological evidence for both the Natufian and the PPNA points to increased exploitation of cereals together with culling of less cost-effective, low-ranked animal resources (Garrard 1999; Smith et al. 1984; Stiner and Monroe 2002). This combination would have resulted in increased energy consumption for smaller returns. The deterioration in health status at this time—inferred from the increased frequency of enamel hypoplasia (Figure 14.7a), indicative of stress in infancy and early childhood—is associated with an abrasive, high-carbohy-

drate diet, as shown by increased frequencies of antemortem tooth loss, caries (Figure 14.7b), and attrition (Figure 14.6) (Smith 1972, 1991; Smith et al. 1984). Processed carbohydrates tend to block absorption of iron and calcium (Rheinholdt et al. 1973), such that a diet rich in carbohydrates may have had a negative impact on nutritional status, especially in women and children, as shown by Fujita and colleagues (2004) for recent agriculturalists.

Although the Early Natufian and PPNA are associated with increased intensity of site occupation and population density, a factor known to promote the maintenance and spread of pathogens (Cohen 1989; Strassman and Dunbar 1999), the human remains show little evidence of skeletal pathology indicative of infectious disease. Such pathology as is present is most prevalent in the more mobile Late/Final Natufian sample. Thus, the overall devolution in health status during the Late/Final Natufian–PPNA may be attributed to deterioration in diet and nutrition, compounded by increased competition for resources and augmented energy outlay for diminishing returns.

In the MPPNB, the decline in health status is reversed. There is little evidence of skeletal pathology, hypoplastic defects of the teeth occur in fewer individuals, and skeletal robusticity appears to have equalled or exceeded that of the Natufians (Peterson 1997, 1998; Eshed et al. 2004b). These findings may be solely attributable to altered patterns of activity and lifestyle affecting upper arm musculature but, when combined with the other evidence for taller, healthier people, suggest a reliable and nutritious diet. This correlates with the archaeological evidence for cultivation of cereals and legumes, as well as meat and possibly milk from goats, which were undergoing domestication (Garrard 1999; Horwitz et al. 1999; Horwitz 2003). This explanation, rather than the alternative of gene flow from demic diffusion, is supported by the similar frequency of inherited characteristics of the teeth, such as a high frequency of large Carabelli's cusps, the small size of second molars and premolars, the presence of lingual tubercles and developmental grooves in upper lateral incisors, and a high frequency of third molar agenesis, within both Natufian and Neolithic populations from the Southern Levant (Smith 1991, 1995).

A dramatic decline in health occurred subsequently in the LPPNB–PPNC. It differs in etiology from that observed in the Late/Final Natufian–PPNA in that it is characterized by signs of infectious disease such as tuberculosis and malaria (Hershkovitz et al. 1991; El-Najjar et al. 1997) and severe skeletal pathologies that include periostitis, cortical hypertrophy, and meningo-encephalitis (Schultz 1987; Schultz and Sherer 1991). At all sites studied, this is also expressed in the location and frequency of enamel hypoplastic defects. The location of hypoplastic defects on the teeth of MPPNB and earlier populations indicates stress at 3–5 years of age, as opposed to 1–5 years in the LPPNB and

PPNC. This may reflect the effect of early weaning practices, common in traditional agricultural societies (Smith and Peretz 1986; Goodman and Armelagos 1989), combined with increased exposure to infectious diseases.

Female stature in the PPNC is the shortest for any period discussed here and may reflect gender differences in control of resources, which (if accompanied by increased fecundity) would have been aggravated by early and multiple pregnancies. Although it has frequently been claimed that males are more sensitive than females to environmental change, this is often offset by preferential nurture of male infants. The total number of offspring also plays an important role in determining stature. Acheson (1960) noted that in post–World War II England, stature decreased with birth order and that this phenomenon was especially marked in females.

Beinert (2001) proposed that in terms of size, complexity, and richness of architecture, material culture, and social structure, many LPPNB sites may be perceived as proto-urban in character. Increased group size, population density, and sedentism all contribute to and facilitate the maintenance of infectious diseases so that LPPNB populations may have experienced medical problems similar to those typical of more recent, urban societies lacking adequate sanitation and medical care (McNeill 1976; Cohen 1989). This would account for poor health despite the expanded dietary base available by the LPPNB, which included cultivated plants as well as domestic goats and sheep and possibly also domestic cattle.

The LPPNB–PPNC sequence is characterized by the widespread abandonment of many sites and contraction of others, together with the establishment of new settlements in marginal regions such as deserts and the marshy coastal plain (Rollefson and Köhler-Rollefson 1989; Galili et al. 2003). This shift in settlement pattern has been attributed to cultural degradation of the environment through deforestation and overgrazing, resulting in the decimation of local resources (Rollefson 1996; Rollefson and Köhler-Rollefson 1989), as well as increased aridity with the cessation of summer rainfall (Simmons 1997).

The timing and character of the deterioration of health in the LPPNB–PPNC suggests that this may not have been solely related to resource stress but also to the side effects of animal husbandry through increased proximity and interaction between humans and domestic animals. The latter would have served as reservoirs for the development, spread, and maintenance of zoonoses (Smith and Horwitz 1998; Horwitz and Smith 2000). We propose here that many endemic diseases became established in the wake of animal domestication and that their initial impact (that is, deterioration in health status) may even have contributed to the destabilization of LPPNB communities, resulting in the observed shift in settlement patterns in the PPNC.

Well over a third of the 868 pathogens currently associated with infectious

diseases in humans are zoonotic in origin (McNeill 1976; Brothwell 1991; Taylor et al. 2001; Weiss 2001). Moreover, the number of diseases shared with humans is correlated with the length of time that a species has been domesticated. Goats, sheep, and cattle share some 46 diseases with humans, several of which are transmitted by insect bites and others through ingestion of infected meat, blood, or milk. Pigs, possibly a late domesticate, have fewer shared diseases, whereas dogs—the earliest domesticate and the one most closely integrated into the human sphere—have the highest number, 65 diseases (Horwitz and Smith 2000).

The rate of transmission of zoonoses and reinfection from animal-borne diseases in Natufian and Early Pre-Pottery Neolithic A populations would have been limited because dogs were the only domestic animal at this time (Tchernov and Valla 1997). Moreover, they were probably kept in low numbers and as hunting companions rather than for food. However, once animal domestication was established, infectious diseases became endemic and were maintained in even small groups of seminomadic pastoralists through cross-infection. Prior to the introduction of antibiotics, the infectious disease load of traditional nomadic and semi nomadic Bedouin groups in the Southern Levant was as high as that of contemporary sedentary agriculturalists, especially for tuberculosis and other respiratory infections (Freund 1939; Klopstook 1939; Ashkenazi 1956). This has been attributed to close contact with domestic animals acting as a reservoir for zoonoses, exacerbated by poor hygiene and crowding in poorly ventilated tents, especially during the winter months.

Conclusions

The skeletal findings presented here indicate that the transition to agropastoralism in the Southern Levant was characterized by two low points in human health: the first during the Late/Final Natufian–PPNA and the second during the LPPNB–PPNC. Archaeological evidence shows that these nadirs in health status occurred against a changing background of environmental stress reflected in the abandonment or contraction of many settlements or a change in site occupation intensity. The devolution of human health in the Natufian–PPNA ended by the MPPNB, when the trend towards skeletal gracilization was also arrested or even reversed. This is expressed in increased skeletal robusticity, increased limb bone diameters, pronounced muscle markings, increased male stature, and a reduction in the severity of dental hypoplasia and skeletal pathology. These features suggest that MPPNB populations were healthier than those of the Final Natufian and PPNA, a finding that may reflect improved nutrition based on agriculture and ready access to meat and possibly milk from goats in the early stages of domestication.

This improvement was short-lived. In the LPPNB–PPNC, health status declined and was associated with a high frequency of chronic stress expressed in dental hypoplasia and skeletal pathologies associated with infectious disease. This occurred despite the adoption by this time of fully fledged agropastoralism. Poor health status continued and was even exacerbated in subsequent periods (Smith 1995; Smith and Horwitz 1998). Although climatic change and environmental degradation may have contributed to stress from periodic food shortages, we propose that the poor health characteristic of the Late Neolithic and subsequent Chalcolithic was primarily owing to a high endemic disease load in which zoonoses played a major role. Although offering a more viable means of increasing subsistence returns in an impoverished natural environment, domestic animals played a negative role by establishing infectious diseases and ensuring their maintenance in these and subsequent populations.

15

The Health of Foragers

People of the Later Stone Age, Southern Africa

SUSAN PFEIFFER

Descriptions of the morbidity and mortality of contemporary or historically documented hunter-gatherers can, with caution, shed some light on earlier populations (Eaton and Eaton 1999; Jenike 2001; Kelly 1995; Panter-Brick et al. 2001; Truswell and Hanson 1976). These recent people cannot provide a full picture of past peoples' health because, as a result of limits set by dominant groups such as colonists or state governments, they have lost access to rich environments, activities, and mobility once available to their ancestors. Skeletal remains of past foragers living in a world populated only by other foragers can form the basis for a more informed understanding of the story of human cultural evolution.

Regrettably, the low population density and the paucity of studies in this area lead to small skeletal samples and reduced archaeological visibility, limiting the value of observations. This problem has partly been solved by linking many small samples into regional overviews.

Holocene Foragers of the Cape

The skeletal remains reported in this survey come from archaeological sites in the Cape Fold Mountains, the coastal platform, and the rocky shorelines where southwestern and southern Africa meet the South Atlantic and Indian oceans (Figure 15.1). The region studied, a portion of the Cape Ecozone (Deacon and Lancaster 1988), can be divided into western, southern, and eastern parts. The western region consists of wide, sandy coastal lowland with a Mediterranean climate of mild, wet winters and hot, dry summers. Annual rainfall ranges from less than 200 to slightly over 1000 millimeters per year (Anonymous 2003). Coastal resources of the western Cape are linked to the productivity of the South Atlantic Ocean. The climate of the southern Cape is warm and temperate, with year-round rainfall ranging between 700 and 1200 millimeters per year (Anonymous 2003). The coastal resources of the southern Cape reflect the productivity of the Indian Ocean. Both study areas are character-

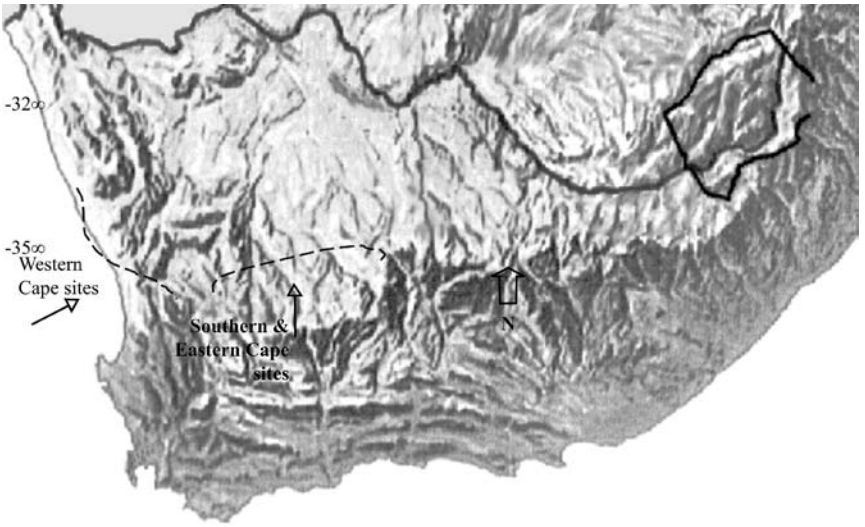

Figure 15.1. Map of the study area in South Africa.

ized by *fynbos* vegetation ("fine leaf" shrubs and bushes) that provides edible corms, fruits, and seeds and supports mainly small-to-medium-sized mammals. This combines with succulent *karoo* zones in the west and *afromontain* vegetation in the south. The eastern Cape is a complex transitional zone, where the Cape Fold Mountains diminish, meeting the interior grasslands and the eastern coastal plain. Rainfall is not seasonally patterned. Throughout the Cape Ecozone, fynbos vegetation combines with marine resources that include shellfish, near-shore fisheries, bird nesting areas, and seal rookeries. The region is well south of the malaria zone.

Archaeological evidence of Later Stone Age foragers in the Cape region is extensive, with good preservation, particularly in shell middens, dry rock shelters, and sand dune deposits. The initial Holocene stone tool assemblage known as Oakhurst (or a variant known as Albany) was replaced by the Wilton assemblage in the first half of the Holocene. All Later Stone Age assemblages include more bone, shell, and ostrich eggshell artifacts than do the earlier Middle Stone Age complexes. Variation in the proportions of small scrapers, bladelets, and adzes are some of the regional distinctions that permit reconstructions of foraging adaptations (Mitchell 2002). At the end of the Pleistocene, evidence of light-draw bows (and presumably poison-tipped arrows) first appears (Parkington 1998; Wadley 1998). Evidence from upper arm strength and asymmetry indicates the establishment of a gender-based division of labor: women focusing on work with digging sticks and grinding; men hunting,

favoring spears in the southern region and light-draw bows in the western region (Pfeiffer and Stock 2002; Stock and Pfeiffer 2004).

Tool styles, technology, and symbolism of rock art affirm continuity between Holocene foragers and pastoralists of the region and living peoples of southern Africa who speak Khoesan languages—the Ju/'hoansi (Lee and Biesele 2002) and the Khoekhoe (Deacon and Deacon 1992; Mitchell 2002).

Patterns of foraging during the Holocene show temporal and geographic variability. It has been argued that geographically extensive exchange networks analogous to the *hxaro* (gift exchange) practiced by Ju/'hoansi of the modern era were operative by circa 12,000 years ago (Wadley 1987). By mid-Holocene times, the ranges of at least some Later Stone Age groups appear to have been firmly delimited, and each community's food procurement was adapted to local conditions (Sealy and Pfeiffer 2000). At least in the western Cape, there were instances of interpersonal violence at around 2600 BP (Morris and Parkington 1982; Morris et al. 1987; Pfeiffer et al. 1999; Bahn 2003; Pfeiffer and van der Merwe 2004). This may correspond with changes to Later Stone Age economies, as they became increasingly characterized by delayed, rather than immediate, returns from hunting and gathering (Hall 1990; Jerardino-Wiesenborn 1996) and as the landscape became more crowded.

Bones of caprines and pottery appear at some archaeological sites dating to approximately two thousand years ago, signalling the introduction of pastoralism, either by trade or by southward movement of Khoesan peoples from the northwest. For the next millennium, the occupants of the Cape showed variability with regard to subsistence. There is debate regarding whether communities of foragers and pastoralists can be distinguished. The term "hunters-with-sheep" has been suggested (Sadr 2003).

At about the same time, farmers (Bantu ancestors of today's Black African peoples) moved southward on the east side of the continent, bringing with them metallurgy, domesticated cattle, and millet cultivation (Huffman 1993). They are often characterized as "Iron Age." These populations relied on soils found in the interior and eastern coastal plain that would support millet cultivation and the grazing of cattle. Usually they did not compete directly with the Bushmen, who preferred the fynbos and coastal locales of the south and west. Southern Africa is not a region where a "transition" to agriculture occurred. The farmers arrived from the north, occupied grasslands that had been relatively unattractive to the foragers, and coexisted with them.

A few hundred years after the arrival of the first foreigners (the Black farmers), the second wave of foreigners arrived: Europeans and Arabs, landing on the western and eastern coasts. From that point (the early fifteenth century AD), the Bushmen became part of African history. High rates of Bushman

mortality were associated with disease, disruption, and overt conflict among groups. Today, the descendants of the Holocene foragers live primarily in the Kalahari region—a habitat that differs greatly from the cooler, wetter habitats that were favored by their ancestors.

Assumptions of This Study

Despite regional variability and change, there is evidence for broad-based and stable adaptations among the Holocene foragers of the Cape. Tool kits, subsistence behaviors, and social organization are broadly similar (Deacon and Deacon 1999; Mitchell 2002). Biomechanical analyses of long bones indicate reliance on terrestrial mobility (Stock and Pfeiffer 2001), consistent with an apparent lack of watercraft or exploitation of offshore resources. Surface features of ankle and knee joints indicate deep squatting postures and lean physiques (Dewar and Pfeiffer 2004). Adult stature is petite, like that of historic Khoesan peoples (Pfeiffer and Sealy 1998; Sealy and Pfeiffer 2000; Smith et al. 1992; Wilson and Lundy 1994), except for periods in which stature was even shorter (Smith et al. 1992; Wilson and Lundy 1994; Pfeiffer and Sealy 2006). Dental caries rates (all tooth types) are 2.6 percent for the western Cape (Sealy et al. 1992) and from zero to 17.7 percent for samples from the southern Cape (Drennan 1929; Sealy et al. 1992). Wear patterns are consistent with mastication of tough, sometimes gritty food. The teeth of adults who ate large proportions of marine foods are more worn and less carious than the teeth of those who relied on more terrestrial foods (Sealy and van der Merwe 1988).

For each of the variables being reviewed here, temporal and geographic variability has not been found. Despite the dispersal of the skeletal remains across this broad region, these remains can be treated as a single population.

Materials and Methods

Skeletal remains reviewed here are derived from archaeological sites throughout the Cape. Aggregate burials are common in the southern Cape, with Matjes River Rock Shelter being the largest site there, and smaller groupings being the norm in eastern and western regions. Many of the latter are single, isolated sand dune burials. Each skeleton has either a ^{14}C date directly associated with it or an archaeological context that provides a temporal context. Skeletons that may represent the transition to pastoralism are not included in this work.

Adult skeletal remains, mostly complete but sometimes very fragmentary, represent a minimum of 152 individuals, from the western (56), southern (72), and eastern (24) Cape regions. Sex and age are determined by standard osteological criteria, with emphasis on pelvic indicators of sex, and pelvic and

rib indicators of age. Juvenile skeletal remains include 58 infants, juveniles, and adolescents. Estimates of their age at death are based on dental formation standards and/or by diaphysis lengths, with diaphyses of Later Stone Age used as the reference sample (Sealy et al. 2000). The remains are curated at institutions in Johannesburg, Grahamstown, Bloemfontein (Florisbad), and Cape Town (Morris 1992a). The author has focused on major long bones and pelves. Adult crania, dental remains, ribs, and the bones of the hands and feet are not systematically addressed.

Indicators of Health from Adult Remains

EVIDENCE OF DISEASE AND ACHES AND PAINS

No instances of infectious processes were identified among adults, despite close examination of the pleural surfaces of ribs and attention to potential periosteal response on all bone surfaces. One adult male from the mid-Holocene does display a pervasive hypertrophic bone condition, of unknown etiology (D. Stynder pers. comm., 2004).

Synovial joints tend to show little osteophytic lipping and rarely any chondral destruction. Vertebral bodies are frequently free of osteophytes, and age-related compression is rare (discussed below). The elbow and—at one site (Oakhurst; Patrick 1989), if not more—the first metatarsal are the most affected. Potentially disabling levels of osteoarthritis are rarely seen. One case, an older (>50 years of age) man from the southern Cape, is reported to have had anterior fusion of L4–L5 (perhaps subsequent to a collapsed disk) and marked bilateral eversion of the first metatarsal-phalangeal joints. The marked varus position (-29° on the right, -19° on the left) is said to be the result of extensive osteoarthritic lipping (Morris et al. 1987). Eburnation on one or more synovial joints, including two first metatarsals (proximal), two knees, one humerus head, and two sets of elbows, was noted in six skeletons, most of which show signs of advanced age. One older man's hand bones (ALB 131) show bilateral eburnation of various wrist bones plus erosion of at least one proximal metacarpal in a manner that may reflect a rheumatoid type of arthritis. The pelvic joints of a small number of women (both pubic and sacroiliac) show eburnation, possibly reflecting the sequelae of childbirth.

HEALED FRACTURES

Frequency and location of healed fractures of major long bones help quantify the risk of accidental injury and the amount of time during which members of a foraging group might have been disabled. To date, there is no evidence of

healed or healing bone fractures among infant, juvenile, or adolescent remains in the Late Stone Age. Healed fractures among the adults are described here.

The long bones included in this tally come from all 152 adult skeletons. Most have been radiocarbon dated as older than 1500 BP. A few more-recent skeletons come from archaeological contexts suggesting association with foraging groups.

Of 1,353 long bones observed (clavicles, humeri, ulnae, radii, femora, and tibiae), almost 1,000 are complete enough to have a full set of basic osteometric measurements. The less complete bones that are included were judged complete enough that a healed fracture would not be missed, but it is possible that these data slightly underrepresent the number of healed fractures.

Of the 152 skeletons (61 female, 74 male, 17 of undetermined sex), 12 (7.9 percent) show healed fractures. One has both a healed Colles fracture and a broken ulnar styloid on her left arm; the other 11 skeletons have one fracture each. Those affected include 3 women, 8 men, and 1 person of undetermined sex (but probably male). The fractured bones include one right clavicle, one right and two left humeri, one right and four left radii, three left ulnae, and one left tibia (a break to the medial malleolus). Of the affected skeletons, 7 are from the southern Cape and 5 are from the western Cape; none is from the eastern Cape. The distribution of their burial sites mirrors that of the sample as a whole. All affected skeletons have been radiocarbon dated. The skeletons' radiocarbon dates range widely. Three date to 9000–10,000 BP (out of 9 dated skeletons from this time range), 1 (of 15) to 5000–6000 BP, 8 (of 70) to 2000–3000 BP, and 1 (of 6) to ca. 1000 BP.

Of the skeletons examined, almost 8 percent had a healed long bone fracture. Men were more than twice as likely to have a healed break (11 percent of men, 5 percent of women). Of thirteen affected long bones, only three are from the right side. The most common healed fracture location is the left forearm. Given the rarity of dated skeletons greater than 8,000 years old in this sample, there may be some functional significance to the large proportion showing healed fractures.

These patterns can be compared with those from other prehistoric populations (Table 15.1). A skeletal sample from Sudanese Nubia (Kilgore et al. 1997) displays a much higher prevalence of healed long bone fractures (48 of 146 adults), although the groups lived in similarly rugged regions. When compared with prehistoric foraging peoples of Kulubnarti, the Atacama region of Chile, and central California, the South African Later Stone Age adults show the lowest proportion of healed fractures in four of the six bones tallied. This comparison ignores sampling problems and age at death as a variable. It also ignores vulnerable small bones and vertebral compression fractures (the latter a category of fracture that can reflect trauma, low bone mass, or both).

Table 15.1. Comparison of Prevalence of Healed Trauma in Later Stone Age versus Other Forager Populations

	LSA		**Kulubnarti**		**Atacama**		**Cent. Calif.**	
Bone	*N*	%	*N*	%	*N*	%	*N*	%
Clavicle	174	0.6	262	0.4	408	2.2	291	0.7
Humerus	230	1.3	276	3.6	423	0.2	300	0.3
Radius	180	2.8	259	6.2	402	4.2	301	4.3
Ulna	194	1.5	260	13.1	412	4.1	290	5.2
Femur	224	0.0	281	1.1	427	0.7	313	0.0
Tibia	197	0.5	232	0.0	403	0.7	315	1.6

Sources: For Kulubnarti, see Kilgore et al. 1997; for Atacama, see Neves et al. 1999; for central California, see Jurmain 1991.
% = percentage of healed fractures within each skeletal sample; LSA = Later Stone Age; Cent. Calif. = central California.

Vertebral compression fractures to the lower thoracic and lumbar regions do occur among South African Holocene foragers, perhaps contrary to expectation (Agarwal and Grynpas 1996). Six adults (four men and two women) show significant compression of at least one vertebra from the T12 to L5 region. In one case (a man 50 years of age, or older), the skeleton shows compression of T12 and L1, rib fractures, and a Colles fracture to the left radius. These healed breaks may reflect recovery from one traumatic event that caused multiple injuries, or the accumulation of various injuries combined with age changes through a long life.

TOOTH SIZE

Rapid tooth wear, associated with a tough, gritty diet, is common among adult dentitions from the preceramic South African Cape. Interproximal and occlusal wear confound accurate measurements of maximum crown dimensions. Nevertheless, some information is available about molar crown dimensions.

The teeth of historic Bushmen are small (Coon 1965), representing the lower range of modern human variation. If dental size reduction is linked to the physiological effects of environmental stressors during development, this reduction might in turn be linked with deleterious living conditions among the historic Bushmen. The question is whether their foraging ancestors had significantly larger teeth.

The dentitions of juveniles and very young adults were used to measure permanent molar dimensions, using teeth that have not yet lost substantial enamel through dietary wear. The first and second molars from 41 dentitions (7 female, 20 male, 9 adults of undetermined sex, 5 juvenile) from nine archaeological sites were measured. The maximum mesiodistal (MD) and buccolingual (BL) diameters were measured using standard vernier calipers for all

Table 15.2. Summary Statistics of Mandibular Molar Mesiodistal (MD) and Buccolingual (BL) Maximum Diameters (mm) and Occlusal Areas (mm^2)

		N	Mean	SD
Historic Bushmen[a]				
Males				
M1	MD	118	10.85	0.69
	BL	118	10.52	0.48
	Area		114.1	
M2	MD	118	10.62	0.67
	BL	118	10.43	0.57
	Area		110.8	
Females				
M1	MD	130	10.74	0.71
	BL	128	10.37	0.48
	Area		111.4	
M2	MD	126	10.47	0.66
	BL	125	10.25	0.57
	Area		107.3	
Sexes pooled[b]				
M1	MD	248	10.79	
	BL	246	10.44	
	Area		112.7	
M2	MD	244	10.37	
	BL	243	10.21	
	Area		105.0	
Later Stone Age				
M1	MD	21	10.91	0.42
	BL	21	10.52	0.38
	Area	21	114.9	7.89
M2	MD	24	10.80	0.65
	BL	24	10.54	0.58
	Area	24	113.9	12.64

Note: Values in bold are significantly greater than historic values, sexes pooled ($p<.01$). M1 = first mandibular molar; M2 = second mandibular molar.

[a] Dimensions from Van Reenen 1966; areas calculated.

[b] Weighted averages.

BL diameters. MD diameters were measured with standard vernier calipers if the teeth were loose and with sliding needle-point calipers if the teeth were in the jawbone. When dental antimeres were available, left and right average values are used in comparisons. Occlusal area was also calculated by multiplying MD and BL values.

Compared to the odontometric range of modern humans (Hillson 1996), Later Stone Age molars are rather small. The mandibular molar dimensions (M1 and M2) have been compared to dental measurements taken from living Bushmen of the twentieth century (Van Reenen 1996). These odontometric

data are derived from large numbers of Bushmen, including both nomadic and settled people and individuals of all ages with varying degrees of occlusal wear. The historic tooth size data are published only with the sexes separate. Many of the Later Stone Age values cannot be divided by sex, so weighted averages have been calculated for the historic values.

The sizes of first and second mandibular molars are generally comparable (Table 15.2), consistent with an ancestor-descendant relationship. Nevertheless, values for the Later Stone Age molars are absolutely larger than those of the historic sample with sexes pooled. Differences are statistically significant for the dimensions of the second molar (one sample *t*-tests). The apparent dental reduction cannot be clearly linked to a subsistence change from foraging to pastoralism or agriculture, although the historic Bushmen were living in a very different foraging habitat from that of their mid-Holocene ancestors.

Indicators of Health from Juvenile Remains

EVIDENCE OF DISEASE

Of the many immature forager skeletons that have been surveyed, only one shows systemic skeletal indications of disease. The skeletal remains of an infant (approximately 4 to 5 months of age) from a rock shelter at Byneskranskop (SAM-AP 6060) show pervasive abnormalities that are consistent with the effects of hypertrophic (hyperplastic) rickets. Diagnostic features include beading of the costochondral junctions of the ribs, flaring and tilting of the metaphyses, and cupping of the distal ulna, as well as general skeletal hypertrophy. Porous thickening is especially noteworthy in the frontal-orbital region of the skull. It is described in detail elsewhere (Pfeiffer and Crowder 2004).

With an uncalibrated AMS radiocarbon date of 4820±90 BP (TO-9531), this is a very early instance of this condition, among foragers whose environment and diet preclude shortages of active vitamin D or dietary calcium. The infant was buried in a manner like that of other deceased group members, including red ochre. This case illustrates the ability of Holocene foragers to maintain ill family members, at least briefly. Likely causes of hypertrophic rickets in this infant could include functional abnormalities of the liver or kidneys, or an inborn error of metabolism. No skeletal indication of infectious disease has been identified among the forager children of the Cape, to date.

CRANIAL INDICATORS OF ANEMIA

Complete and partial crania from 48 juveniles (not including the case of hyperplastic rickets) from western, southern, and eastern locales were examined for the presence of cribra orbitalia (CO) and porotic hyperostosis (PH). Only 1

Table 15.3. Cribra Orbitalia in Crania of Forager Children

Age Class	Sample *N*	Cribra *N*	Cribra %
Infant (<1)	14	1	7.1
1–3	6	3	50.0
3–6	11	2	18.2
6–11	6	5	83.3
12–15	6	2	33.3
Total	43	13	30.2

Note: Ages are in years. All instances are slight to moderate in extent.

of 47 cranial vaults shows PH: an infant (estimated at 0.5–1 year of age) from Matjes River Rock Shelter shows moderate bilateral porosity on the parietals. The orbits are not preserved, and the skeleton is commingled with that of another child, preventing further analysis.

CO is more common, with 13 of 43 available crania showing slight to moderate development of porosity on the orbits. Examined by age class (Table 15.3), the crania show a low frequency of CO in infancy and a high frequency in midchildhood (6 to 12 years). When postinfancy age classes are combined, orbital signs of anemia occur in about 30.2 percent of the children who failed to survive.

GROWTH ARREST LINES

Long bones from 43 juveniles over a broad temporal spectrum, dating from 5,500 to 1,800 years ago, could be radiographed to assess evidence for growth arrest. Of these individuals, 21 are from the eastern Cape, 12 from the southern Cape, and 10 from the western Cape.

Growth at eight growth sites (left and right distal femora and radii and proximal and distal tibiae) per skeleton was quantified. In 13 individuals, all eight sites are extant, whereas 3 individuals are represented by a single site of evaluation; most individuals are represented by multiple sites. To be counted, a line had to be clearly visible and extend more than halfway across the width of the shaft. Despite excellent radiographs, there is still some uncertainty about these features, particularly if a line is located very near the metaphysis, where there might be a shadow of the growth plate. Therefore, the results are summarized in a fashion that distinguishes long bone ends at which single growth arrest lines were recorded. Interpretive emphasis is given to patterns with two or more lines.

The results are summarized by age class in Table 15.4. Not surprisingly, growth arrest lines are uncommon among infants who died at less than one

Table 15.4. Radiographically Visible Growth Arrest Lines from Forager Children, Birth to Fusion of Long Bones

Age Class	Juvenile Individuals *N*	Growth Sites *N*	Sites with ≥1 Lines %	Sites with ≥2 Lines[a] %	Persons with ≥1 Lines %	Persons with ≥2 Lines[a] %	Persons with ≥2 Lines[a] at Multiple Sites %[b]
Infant (<1)	13	78	65.4	3.8	19.2	15.4	0
1–3	7	32	34.4	12.5	71.4	57.1	0
3–5	7	35	60.0	22.8	85.7	42.9	28.6
6–11	10	57	52.6	31.6	90.0	70.0	30.0
12–15	6	36	36.0	11.0	66.0	33.3	16.7
Totals	43	238	52.9	15.5	67.4	41.9	14.0

Note: Ages are in years. Tally is from distal ends of femur and radius, proximal and distal ends of tibia, a maximum of eight growth sites per skeleton.

[a] Two or more growth arrest lines at one growth site.

[b] As a proportion of juvenile individuals (*N*).

year of age. Two (from the sites of Oakhurst and Spitzkop) of the thirteen infants have at least one growth site with two growth arrest lines. No infant has more than two lines at any growth site, and most infants have none. In the age category of 1–3 years, the frequency of growth sites with two or more growth arrest lines increases, as does the proportion of persons affected. No very young children show multiple sites of multiple lines.

Age classes 3–5 years and 6–12 years show an increasing ratio of growth sites with two or more lines, and individuals with multiple locations of multiple lines. Most children who died in midchildhood show growth arrest lines, and three of the ten show multiple lines at multiple sites. Among the six adolescents (emergence of second permanent molars to fusion of epiphyses), the frequency of lines declines again. This may reflect the effect of rapid adolescent growth, erasing growth arrest lines through remodelling.

There are children with multiple growth arrest lines from all regions, but children from the western Cape comprise a disproportionately large part of those who show multiple lines (6/10).

There appears to be some association between the presence of cribra orbitalia and growth arrest lines. Twenty-four skeletons provide information on both. Of the nine skeletons with cribra orbitalia for which long bones are available, five show two or more growth arrest lines at one or more bone growth sites. Of the fifteen skeletons without cribra orbitalia for which long bones are available, only three show two or more growth arrest lines at one or more growth sites.

Regional Comparisons

A primary purpose of this survey was to provide comparative information against which skeletal and dental patterns of nonforagers could be compared. There are questions to be asked in the context of the transition from foraging to pastoralism. However, current archaeological interpretations suggest that skeletons from the past two thousand years include some whose subsistence strategies shifted back and forth within their lifetimes. As progress is made in identifying the skeletal remains of people with long-term reliance on pastoralism, possible shifts in disease, stress, and trauma can be explored.

Comparisons to Early Farmers

There has been some study of the scanty skeletal remains of early farmers. The common placement of burials beneath the cattle kraal or between the residential huts (Denbow 1999; Mitchell 2002) precludes good bone preservation. Maryna Steyn has conducted analyses of the largest single Iron Age collection, from K2 (also known as Bambandyanalo) and Mapungubwe. These contiguous sites, just south of the Limpopo River, were occupied from AD 1000 to 1220 and from AD 1220 to 1300, respectively (T. Huffman, pers. comm. 2004). Excavated several decades ago, 106 skeletons are extant: 94 from K2 and 12 from Mapungubwe. Steyn notes that tooth decay points to an agriculturist as opposed to a forager diet (Steyn 1997). Comparing juveniles from the two early farmer sites to those from the Later Stone Age site of Oakhurst (circa 9000–2000 BP) (Patrick 1989), Steyn notes that both cribra orbitalia and growth arrest lines (Harris lines) are more common among children from Oakhurst. Steyn argues that the early farmer sample represents a population that was relatively healthy, attributing this to cattle herding as a supplement to cultivation. However, a stable isotope study of 26 early farmer skeletons from Botswana (Murphy 1998) suggests that cattle and their milk were not dominant components of the diet. This latter study also found dental caries to be common. Also reported from the Mapungubwe sample are the modified long bones of a young adult man that have been described as exhibiting possible treponemal disease (Steyn and Henneberg 1995). This may be the earliest documented instance in southern Africa of the bony sequelae of a specific infectious agent.

Explorations of comparative dental health were made by Morris (1992b) in his craniometric study of human contact along the Orange (Gariep) River. In the past two millennia, diverse factors have included a new subsistence strategy (pastoralism), new neighbors (farmers), and new sources of destabilization (explorers/colonists from abroad). The health of foragers might be predicted

to have improved through the introduction of new dietary options and increased food security, but new pathogens and overt group conflict could have had a deleterious effect on the health of foragers. In the coastal regions where foragers alone had existed in the millennia before 2000 BP, foraging had been at least partly supplanted by pastoralism before concerted European colonization began. Modern history has documented the continuing decline, in numbers and in territory, of people who identify as the foragers' descendants: the Ju/'hoansi and the Khoekhoe.

Discussion and Conclusions

Later Stone Age adults were lean and had relatively strongly built lower limbs, consistent with habitual trekking over rough and/or extensive terrain. Despite evidence that some adults lived to advanced ages, degenerative joint changes are uncommon. About 4 percent of adults show one or more joints with eburnation, and 8 percent show healed fractures. At the same time, some adults show extensive dental wear, low bone mass, and vertebral compression fractures, all indicators of advanced age. Therefore, the low frequency of damaged joints may reflect low body mass rather than physical inactivity or consistently brief life expectancies.

Despite careful scrutiny, no cases of infectious disease were found. Based on the skeletons studied to date, infectious diseases appear to have been rare among mid-Holocene populations.

Accidental trauma, as indicated by healed bone fractures, was not as common as has been reported for other foraging populations. The sites of common breaks are similar to those seen in other samples. The absence of any healed major leg fracture may signal that such a major accident was fatal, through factors including shock, loss of blood, and prolonged immobility. Nevertheless, given the rarity of all types of fracture, it may be plausible that small stature and light build were partly protective against major trauma.

Molar sizes, while staying at the "small" end of the global size continuum, are larger than those of historic-era foragers from southern Africa. This may reflect nutritional adequacy of the foraging diet, absence of infectious agents that would disrupt dental development, or other variables.

Chronic stress was particularly common during midchildhood (ages 6–12), as opposed to the earlier years. Unsurprisingly, infants of less than one year of age do not commonly show cribra orbitalia or growth arrest lines. Stable nitrogen and carbon isotope analysis of the large Matjes River Rock Shelter sample suggests that weaning age was relatively late among mid-Holocene foragers, with a gradual dietary transition beginning between two and four years of age (Clayton 2003; Clayton et al. 2006). If we assume that a child's diet was

at least partly the mother's responsibility until weaning was complete, a child's resourcefulness as an independent forager might be most vigorously tested in midchildhood. Other nondietary factors that could affect skeletal growth and cause at least transient anemia include parasites and toxic bites from ticks and other insects, spiders, and snakes.

A justifiable working hypothesis is that Holocene foragers of the Cape could live long lives, exploiting a food resource base that was generally sufficient but could be intermittently inadequate. Small body size may have had a protective effect with regard to joint degeneration and bone fractures. Infectious diseases appear to have had a negligible effect on growth and health. Midchildhood may have been one of the most stressful times in the life course.

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16

Climate, Subsistence, and Health in Prehistoric India

The Biological Impact of a Short-Term Subsistence Shift

JOHN R. LUKACS

A shift to arid conditions stimulated an adaptive response among Chalcolithic cultures (3400–2700 BP) of the Deccan Plateau, western India. Climate change promoted greater mobility and increased dietary diversity at the site of Inamgaon. Prior study of enamel hypoplasia and bone growth in subadults showed that childhood health improved across this transition. Here I determine whether other measures of stress such as dental caries, linear enamel hypoplasia (LEH), and tooth size in permanent teeth exhibit a change with the shift from agriculture to seminomadic foraging at Inamgaon. The prevalence of dental caries and LEH and changes in mean tooth size were determined. Values for Early Jorwe (EJ) farmers (3400–3100 BP) were compared with those of Late Jorwe (LJ) foragers (3100–2700 BP). Permanent teeth exhibit a decrease in caries rates and an increase in tooth size across the transition, but the prevalence of LEH in permanent teeth remains unchanged. Deciduous dental caries rates and tooth size do not change across the transition, though enamel hypoplasia in deciduous teeth declines significantly from farmers to foragers.

In 1984, the database for paleopathology in South Asia included 1,546 specimens: 105 derived from Paleolithic contexts representing hunter-gatherer lifestyles and 1,441 derived from sites with agricultural subsistence (Kennedy 1984). Kennedy addressed paleodemography, nutrition, growth and development, stature, tooth size, growth arrest, and paleopathology. His conclusions were that population density and frequency of paleopathology increased while the quality of nutrition decreased as hunter-gatherers became farmers. In retrospect, two decades later, his analysis suffered from unavoidable limitations: small and variable skeletal samples with uneven geographical and chronological distribution; interobserver error; and the absence of set standards of paleopathological description. His results were impressionistic rather than statistical.

Since 1984, skeletal and dental evidence for paleopathological research in South Asia has increased as a result of the excavation and analysis of large collections from sites in Pakistan and India. Important new collections from Paki-

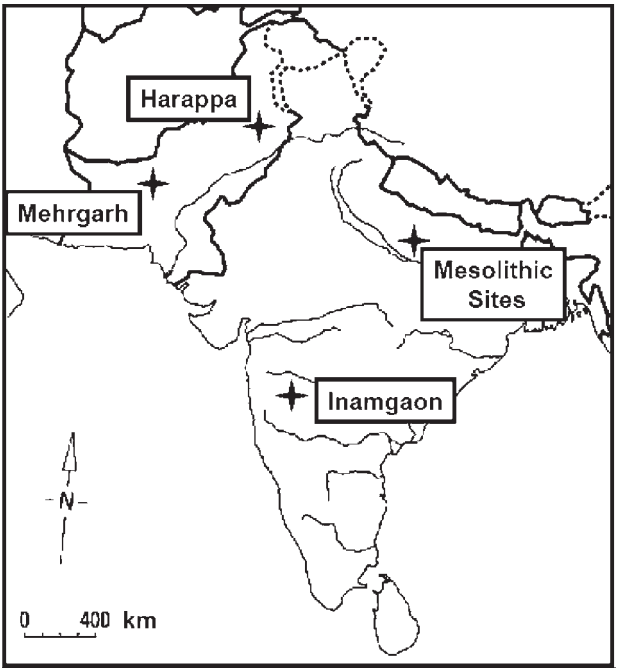

Figure 16.1. Map of the study area with location of sites in South Asia.

stan come from Neolithic (8500 BP; *n*=93) and Chalcolithic samples (6500 BP; *n*=70) at Mehrgarh (Baluchistan province) and from a Bronze Age cemetery (4500 BP; *n*=90) at Harappa (Punjab province). In India, three early- to mid-Holocene (9000–8000 BP) Mesolithic sites in the Ganga Plain (Damdama, Mahadaha, Sarai Nahar Rai) provide almost 100 specimens. An early farming village, known as Inamgaon (3700–2700 BP), on the Deccan Plateau of western Maharashtra has yielded over 220 specimens, 85 percent of which are subadults (infants and children).

These sites add over 573 specimens to the skeletal inventory, permitting statistical documentation of (a) increasing dental pathology with agricultural intensification in the Indus Valley (Lukacs 1992); (b) large tooth size and good dental health among the people of Mehrgarh (Lukacs and Hemphill 1991) and among Mesolithic hunters and foragers (Lukacs 2007; Lukacs and Pal 1993); (c) worsening of women's dental health with the rise of agriculture (Lukacs 1996); and (d) adaptation to climate and the absence of infectious and nutritional diseases among Mesolithic foragers (Lukacs and Pal 2003, 2004). This research presents a picture of dental and skeletal pathology consistent with the general predictions of declining health and tooth size reduction with the adoption of agricultural subsistence.

The human skeletal remains from Inamgaon (Figure 16.1) permit us to

document the biological impact of a short-term reversal in subsistence on dental indicators of stress and nutrition. Chalcolithic Inamgaon appears to have been a chiefdom with a class-structured society (Dhavalikar 1984; Shinde 1989, 1991, 1994). Uniformity of cultures among Chalcolithic villages of western Maharashtra reflects a narrow range of subsistence adaptations elicited by similar environments (Dhavalikar 1984, 1989a).

The change from agriculture to seminomadic foraging at Inamgaon reverses the usual worldwide evolutionary transition (nomadic foragers becoming sedentary farmers). Consequently, we would expect reversed trends in biological consequences. Skeletal and dental health should improve, stature should increase, and the size and robusticity of the masticatory system should increase as foraging resumed.

The goal of this analysis is to test these predictions using three aspects of human dental variation: dental caries, enamel defects, and tooth size. The following three questions are assessed. First, does a decline in dental caries accompany the shift from Early Jorwe agriculture to Late Jorwe hunting and foraging, as we would expect? Second, does the prevalence of linear enamel hypoplasia in adult teeth change during this transition? Changes seen in deciduous dental enamel hypoplasia from Inamgaon suggest that infant and early childhood health and nutrition improved from Early Jorwe farmers to Late Jorwe foragers (Lukacs and Walimbe 1998, 2000). Given this trend, LEH in permanent teeth should also decrease from Early to Late Jorwe, as mobility increased and diet diversified. Third, does tooth size increase across the transition at Inamgaon as would be predicted? Prior statistical analyses of permanent (Lukacs 1985) and deciduous (Lukacs 1981; Lukacs et al. 1983) dental dimensions at Inamgaon pooled all specimens with no separate analysis by sex or cultural phase, because sample sizes were too small to be reliable. Wild foods, less-thoroughly-prepared food, and a coarse, tough diet among the Late Jorwe foragers leads to a prediction of larger tooth size and a more robust jaw structure than is typical of sedentary farmers.

Materials

Inamgaon initially provided only a small and fragmentary skeletal sample. Excavations in 1982–83 resulted in the discovery of twenty-three new burial features, seventeen of which contained human skeletal and dental remains (see the inventory of human remains from the site in Lukacs and Walimbe 1986). Nine of the seventeen skeletons included dental remains, increasing the original sample by 152 teeth (111 permanent, 41 deciduous). Both the original sample and later specimens were included in this study.

Methods

DENTAL CARIES

The fragmentary juvenile skeletons studied required specific conditions for including teeth in the calculation of caries rates. Teeth in fragments of the maxilla or mandible had to be at least 50 percent erupted for inclusion in the analysis. Unerupted and partly erupted teeth (<50 percent) were excluded. Isolated teeth were included when evidence of full eruption (dental wear facets on the occlusal or interproximal surfaces) was discernable with a 10× hand lens. The crown and cervical regions of each tooth were examined under natural light and oblique incandescent light. Examination with the naked eye was supplemented by observation aided by a 10× hand lens. Cavitation of enamel, dentine, or cement attributable to demineralization by acidogenic bacteria was scored as dental caries, following Hillson (2001) and Lukacs (1989). Two methods of reporting dental caries rates were used: the percentage of individuals with one or more carious teeth and the percentage of carious teeth per number of teeth observed. Tooth-count rates are reported for all teeth or for subgroups of teeth by class (for example, molars). Tooth-count caries rates may be based exclusively on the teeth present (observed tooth-count caries rates) or may employ a correction for teeth lost antemortem (corrected tooth-count caries rate) (Lukacs 1995). The same methods were used for deciduous and permanent teeth.

ENAMEL HYPOPLASIA

Enamel hypoplasias were observed under natural light with an oblique incandescent light source (Goodman and Rose 1990). Observations were made on the labial surface of all teeth, but this analysis reports results only for permanent incisors and canines. Observations were made with the naked eye and subsequently with a 10× hand lens. In some instances, a binocular stereomicroscope with variable magnification was used with a fiber-optic light source. The presence of enamel hypoplasia (EH) was recorded by the number of defects per tooth; the number of linear grooves; transverse arrays of pits; or "pit patches" of nonlinear depressed enamel adjacent to the cement-enamel junction (Goodman, Martin et al. 1992). Individual and tooth-count methods of reporting EH are used (Lukacs 1989).

ODONTOMETRY AND TOOTH SIZE

Mesiodistal (MD, length) and buccolingual (BL, breadth) dimensions were measured in millimeters to describe the greatest anatomical length and breadth of the crown (Wolpoff 1971). Measurements were made using a Helios needle-

point dial caliper by one observer (JRL) and were rounded to the nearest 0.1 millimeter. The same observations were repeated after one week to test their reliability. The results reveal a small mean difference between first and second measures (MD=0.076, *n*=46; BL=0.049, *n*=47) and low measures of dispersion (standard deviation: MD=0.168, BL=0.118; standard error: MD=0.025, BL=0.017), suggesting that measurement error is negligible. Approximate occlusal surface area (in square millimeters) was derived by multiplying the MD and BL values. The average of right and left antimeres was used when both right and left sides were present, but if only one side was present, that measurement was used. Mean crown areas represent the arithmetic mean of the product of MD and BL for those teeth in which both measurements were possible, *not* the product of mean MD and mean BL for a particular tooth. Percent change between phases for crown dimensions and crown areas was calculated by the following formula: $[(\bar{x}_{LJ} - \bar{x}_{EJ} / \bar{x}_{LJ}] \times 100$. That is, subtracting the mean of the earlier group (EJ) from that of the later group (LJ), dividing the difference by the mean of the later group, and multiplying the quotient by 100 (Calcagno 1986). This equation yields the same result as another formula often employed in the computation of the percent change between groups: $100 \times [(\bar{x}_{LJ} / \bar{x}_{EJ}) - 1.0]$ (Larsen 1990).

Results

DENTAL CARIES

Any comparison of age-related biological attributes between two groups must demonstrate that the age structure of the two groups is not significantly different. The minimum age at death for including a specimen in the permanent dental caries rate assessment was 7 years. Table 16.1 presents data comparing age-at-death statistics for EJ and LJ phases (mean age at death, standard deviation, and minimum and maximum age at death). No significant differences were found for means or variances. Dental caries rates for EJ and LJ phases at Inamgaon are compared in Table 16.2. The interphase comparison of individual-count caries rates shows a statistically significant decline for permanent teeth. Although the Early Jorwe sample is small, the decline in caries prevalence between the two phases is large: from 43 percent to 11 percent. To verify these results, an interphase comparison of tooth-count caries rates was conducted in three ways: (a) observed rates in the entire dental sample; (b) observed rates in the postcanine teeth only; and (c) corrected rates for postcanine teeth, taking into account antemortem tooth loss attributable to caries (Lukacs 1995). Maxillary and mandibular teeth were analyzed separately and then pooled for interphase comparison of the total sample. Five of the nine comparisons (55.6

Table 16.1. Mean Age at Death for Caries Prevalence Sample

Phase	*N*	Mean	SD	Minimum	Maximum
Early Jorwe	7	22.43	13.99	8.00	40.0
Late Jorwe	35	20.03	13.06	7.00	50.0
Total	42	20.43	13.07	7.00	50.0

Table 16.2. Dental Caries Rates of Permanent Teeth

	Early Jorwe		**Late Jorwe**		**Total**		**EJ vs. LJ**	
Counts	%	*N*	%	*N*	%	*N*	χ^2	*p*
Individual Count	42.9	7	11.4	35	16.7	42	4.159	0.042
Tooth Count (observed/all teeth)								
Maxilla	4.8	63	0.4	229	1.4	292	4.014	0.045
Mandible	2.6	77	1.9	263	2.1	340	0.006	0.938
Total	3.6	140	1.2	492	1.7	632	2.284	0.131
Tooth Count (observed/postcanine only)								
Maxilla	8.1	37	0.0	144	1.7	181	7.420	0.006
Mandible	4.7	43	3.0	169	3.3	212	0.006	0.939
Total	6.3	80	1.6	313	2.5	393	3.844	0.050
Tooth Count (postcanines only, with correction for antemortem tooth loss)								
Maxilla	8.1	37	2.0	147	3.3	184	1.794	0.180
Mandible	12.8	47	4.7	172	6.4	219	2.189	0.093
Total	10.7	84	3.5	319	5.0	403	5.982	0.014

percent) reveal significant differences between phases, and all five significant differences display a reduction in dental caries. Anterior teeth are less susceptible to dental caries than postcanine teeth are, and correction for tooth loss yields more accurate estimates of caries rates. The total-sample comparisons for observed postcanine caries rates and for corrected postcanine caries rates both reveal significant declines in dental caries from the EJ to the LJ phase.

ENAMEL HYPOPLASIA

Results of the analysis of linear enamel hypoplasia (LEH) in the permanent dentition of specimens from Inamgaon are presented by phase and for the composite sample in Tables 16.3 and 16.4. The initial contrast uses the percentage of specimens with one or more LEH defects present in the anterior teeth. This technique detected no significant difference between EJ and LJ samples. The second comparison examines the tooth-count frequency of LEH for each anterior tooth separately. Although three of the six comparisons are significantly different (UI1, UC, and LI1) and two of these show a decline in frequency (UI1 and LI1), the remaining one (UC) shows an increase. The final evaluation in Table 16.4 uses the mean number of hypoplastic lines per tooth as the variable for comparison. In this contrast, two of six means are significantly different. In one case (LI1), the mean number of lines per tooth de-

Table 16.3. Linear Enamel Hypoplasia (LEH) of Permanent Teeth

	Early Jorwe		Late Jorwe		Total		EJ vs LJ	
Tooth	%	*N*	%	*N*	%	*N*	χ^2	*p*
UI1	75.0	8	33.3	27	42.9	35	4.375	0.0365
UI2	40.0	10	52.0	25	48.6	35	NS	>0.05
UC	0.0	3	64.0	25	57.1	28	4.480	0.0343
LI1	83.3	6	37.5	24	46.7	30	4.051	0.0400
LI2	44.4	9	45.0	20	44.8	29	NS	>0.05
LC	66.7	9	63.6	22	64.5	31	NS	>0.05
Total	55.5	45	49.0	143	50.5	188	NS	>0.05

Note: UI1 = upper first incisor; UI2 = upper second incisor; UC = upper canine; LI1 = lower first incisor; LI2 = lower second incisor; LC = lower canine.;% = percentage of teeth with ≥1 LEH; *N* = number of teeth with ≥1 LEH; NS = no significant difference found.

Table 16.4. Mean Number of Linear Enamel Hypoplasias per Tooth

Tooth	**Early Jorwe**			**Late Jorwe**			***t*-test**	
Tooth	Mean	*N*	StdErr	Mean	*N*	StdErr	*t*	*p*
UI1	1.00	8	0.267	0.52	27	0.163	1.44	0.1590
UI2	0.60	10	0.267	0.84	25	0.206	-0.65	0.5178
UC	0.00	3	0.000	0.84	25	0.160	-5.25	0.0001
LI1	1.17	6	0.307	0.42	24	0.119	2.66	0.0127
LI2	0.67	9	0.289	0.55	20	0.154	0.39	0.6991
LC	0.89	9	0.309	0.86	22	0.201	0.07	0.9463

creases, while in the other (UC), the mean increases from EJ to LJ. Collectively, the prevalence of enamel hypoplasia in the permanent teeth from Inamgaon does not show a clear trend.

Results of the analysis of enamel hypoplasia (EH) in deciduous teeth have been reported in detail elsewhere (Lukacs and Walimbe 1998; Lukacs 1999; Lukacs et al. 2001). One form of deciduous EH (LHPC, or localized hypoplasia of primary canines; Skinner 1986) shows a clear and significant reduction in prevalence from Early to Late Jorwe. Another type of deciduous EH, known as IPCH (interproximal contact hypoplasia; Lukacs 1999) exhibits a trend toward declining frequency, though it is not statistically significant. Overall, the prevalence of EH in deciduous teeth suggests an improvement in health with the shift from sedentary agriculture to seminomadic foraging.

ODONTOMETRY AND TOOTH SIZE

Results of the first interphase comparison of diachronic change in dental dimensions for the Inamgaon sample are summarized here.

Data on deciduous dentition are presented elsewhere (Lukacs and Walimbe 2005). Summary assessment of these data reveals no conclusive evidence for consistent directional change in deciduous tooth size from the Early to Late

Jorwe phases at Inamgaon. Only 1 crown measurement comparison out of 20 (5 percent) is significantly different between phases (upper lateral incisor BL decreases). Nonsignificant differences are almost equally divided between increases (9) and decreases (11) in deciduous dental dimensions. Actual and percent change from Early to Late Jorwe is small. Occlusal surface measurements display similar results. No significant differences were observed in occlusal surface area between phases, and total crown surface areas differ by only 2.0 square millimeters when calculated two different ways. Using the sum of mean values for each individual tooth enhances sample size but does not permit a statistical test of the difference between sums (EJ=505.3 mm^2; LJ=502.6 mm^2). Alternatively, using specimens with a full complement of upper or lower teeth permits a measure of variance and a test of mean difference, but this approach results in very small sample sizes. In either case, the difference in crown occlusal area between phases is too small to have biological significance (-2.1 mm^2 [-0.5 percent change] using summed means; -2.65 mm^2 [-0.4 percent change] using complete specimens). In contrast to permanent teeth, deciduous tooth crown dimensions and crown areas apparently are not significantly impacted by the subsistence transition from agriculture to foraging at Inamgaon.

PERMANENT DENTITION

Mean MD and BL crown dimensions, crown areas, and summed crown areas for the Inamgaon permanent teeth are presented in Lukacs and Walimbe 2005. A summary of those data is presented here. Although only 2 of 32 interphase comparisons of crown dimensions yield statistically significant differences in tooth size (BL UI2; BL LC), in 24 of 32 (75.0 percent) comparisons the percent change from Early to Late Jorwe is positive. In 3 comparisons, dental crown dimensions remain unchanged, and in only 5 of 32 (15.6 percent) comparisons is the change negative. The lack of statistical significance is also evident in an interphase comparison of crown areas, yet 16 of 19 (84.2 percent) comparisons show a positive percent increase in tooth size ($\bar{x}$, +5.63 percent; range, +2.3 percent to +12.9 percent). Two factors may have affected the interphase comparisons: (a) that the dental samples being compared are not equal in size, and (b) the small size of the Early Jorwe sample. With larger and equal-sized samples, more of the *t*-test comparisons would be expected to yield significant interphase differences in tooth size.

Brace (1980), in his analysis of tooth size variation among Australian Aboriginals, directly addressed the problem of using incomplete, archaeologically derived dentitions to compute summed tooth crown areas, and he partly resolved the concern over using summed values without variances. His analysis employed only complete specimens, thereby providing measures of dispersion about the mean for total crown areas. Brace revealed that intersample differ-

ences in total summed crown area of approximately 100 square millimeters were statistically significant (α=0.01) and of certain biological significance, whereas differences between samples of about 50 square millimeters were significant to a lesser degree (α=0.05) and of probable biological significance. The interphase difference in total occlusal crown area at Inamgaon is 43.6 square millimeters (LJ crown area of 1235.2 mm^2 minus EJ crown area of 1191.6 mm^2), a value that compares favorably with that suggested by Brace for probable statistical and biological significance.

An estimation of the microevolutionary rate of change in tooth crown area involves several assumptions and calculations (Christensen 1998), yet the procedure provides an approximate basis for comparing the rate of dental microevolution at Inamgaon with rates for archaeological samples in other regions. If the chronological midpoint of each phase is used to approximate the amount of time elapsed between dental samples, the result is 350 years (EJ phase limits are 3400–3100 BP, with a midpoint of 3250 BP; LJ phase limits are 3100–2700 BP, with a midpoint of 2900 BP). If the total crown area increase (43.6 mm^2) is divided by the elapsed time (350 years), the rate of change is approximately 0.125 square millimeters per year. If one generation is 25 years, the interphase comparison using midpoint datum points spans fourteen generations, and the rate of change per generation is 3.11 square millimeters. If the rate of change is computed using the earliest date for the EJ phase and the terminal date for LJ phase, the rate of dental size increase between phases is halved.

Discussion

DENTAL CARIES

The subsistence transition from hunting and collecting to agriculture and the intensification of agriculture is generally associated with a significant increase in dental caries rates in most regions of the world (Larsen 1995; Larsen et al. 1991; Hodges 1987; Lukacs 1992; Turner 1979). The decline in dental health with the rise of agriculture and food-processing technologies impacts women more than men (see Larsen 1998; Larsen et al. 1991; Lukacs 1996; Lukacs and Largaespada 2006). This association has recently been questioned on the basis of evidence from rice agriculturalists in Southeast Asia (Tayles et al. 2000). Data from Mesolithic and Neolithic sites in Portugal also suggest that declining oral health does not always accompany the transition to agriculture (Jackes et al. 1997). The human biological response to agriculture may be more context specific than was once envisioned by researchers such as Cohen and Armelagos (Cohen and Armelagos 1984; Cohen 1989). Interacting variables include the cariogenic nature of food(s), food processing, variation in key elements

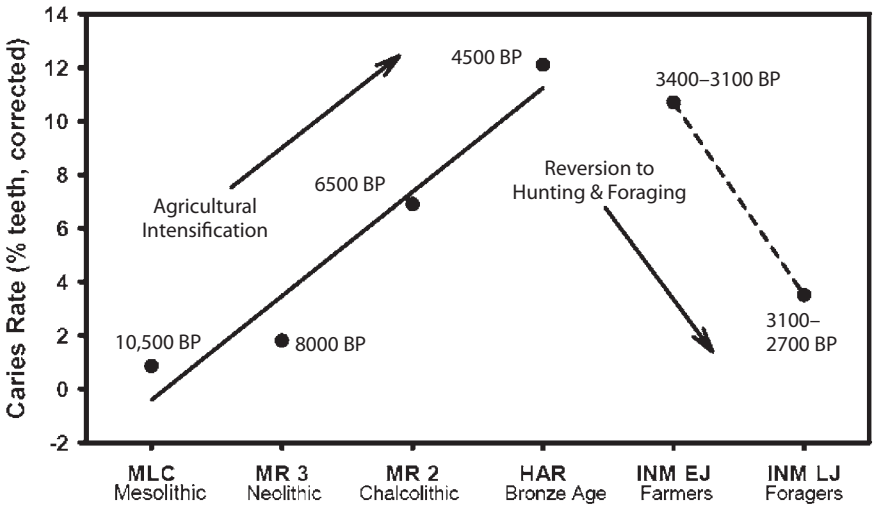

Figure 16.2. Caries rates at various South Asian sites: *MLC*, Mesolithic Lake Culture, including Damdama, Mahadaha, Sarai Nahar Rai; *MR 3*, Neolithic, Mehrgarh (8500 BP); *MR 2*, Chalcolithic, Mehrgarh (6500 BP); *HAR*, Harappa; *INM EJ*, Inamgaon, Early Jorwe; *INM LJ*, Inamgaon, Late Jorwe. Data from Lukacs 1992 and Lukacs and Pal 1993.

such as fluorine and selenium, genetic determinants of dental microstructure and composition, and culinary practices.

There is a positive association between dental caries and agricultural intensification in South Asia (Figure 16.2; Lukacs 1992; Lukacs and Pal 1993), but there is also a significant decline in dental caries as farmers revert to foraging at Inamgaon. Individual-count caries frequency and two methods of tooth-count frequency (total observed for postcanine teeth and total corrected postcanine teeth) all display a significant reduction in dental caries.

ENAMEL HYPOPLASIA

A decline in enamel hypoplasia of permanent teeth should accompany the shift from agriculture to foraging (congruent with the pattern observed in deciduous teeth) because mobile foraging for wild foods increases dietary diversity and the intake of essential nutrients, resulting in healthier people, tending to suffer less physiological disruption than sedentary agriculturalists with a less diverse and less nutritious diet. However, the Inamgaon findings do not conclusively support that expectation. The percentage of individuals with one or more linear enamel hypoplasias is not significantly different between phases. Comparisons between the percentage of teeth affected and the mean number of defects (lines) per tooth show inconsistent results. Two comparisons (UI1 and LI1) exhibit a significant decline in the percentage of affected teeth; three

comparisons show no difference between phases; and one has an inadequate sample size for reliable comparison. In addition, the total tooth-count frequencies are not significantly different. Nonsignificant interphase differences predominate when the mean number of linear defects per tooth is considered: four of six comparisons are not significantly different; one shows a significant decline; and one increases significantly, but sample sizes are minuscule. This analysis yielded no unequivocal decline in the prevalence of linear enamel hypoplasia in permanent teeth, and the logical conclusion is that the frequency of physiological disruption in early childhood at Inamgaon was approximately similar among the Early and Late Jorwe populations. However, the ultimate etiological factors responsible for LEH frequency may be significantly different for each phase.

LEH is widely agreed to be a reliable, indelible, and retrospective indicator of nutritional stress (Skinner and Goodman 1992). Ten studies in Cohen and Armelagos 1984 that included samples bridging the transition to agriculture found an increase in frequency and/or severity of LEH in farming and later populations in comparison to hunter-gatherers, suggesting more frequent and/or more severe episodes of stress in later groups. However, we now know that normative models of hunter-gatherer diet obscure the wide range of existing diversity and that energy, not protein, was probably the most significant limiting resource for most hunter-gatherers (Jenike 2001). Seasonal energy deprivation is known to affect growth, physical activity, and the ability to absorb essential macronutrients. These recent perspectives are consistent with results from prior research on South Asian human skeletons that reveal (a) high levels of LEH among Mesolithic foragers of Damdama in the Ganga Plain, who despite seasonal growth disruption attained tall stature (180 centimeters for males and 170 centimeters for females; Lukacs and Pal 1993); and (b) rates of LEH among intensive agriculturalists of urban Harappa that fall between the high and moderate values for hunting and foraging groups from Mahadaha and Damdama in north-central India (Lukacs 1992). Seasonal food shortages among hunter-gatherers may reflect natural variation in availability of wild food resources. Among agriculturalists, resources may be limited by factors such as crop failure, limited storage, preservation, and seasonal hunger prior to the harvest.

Many studies detecting a significant increase in LEH with the onset of agriculture focused on prehistoric North Americans whose transition from wild foods to maize had dramatic consequences for health and growth. In South Asia, the cultigens adopted (barley, wheat, rice) provided better nutrition than maize, so the association of LEH with subsistence in prehistoric India is not as clear. The shift from farming to foraging at Inamgaon was not sufficient to alter the relative frequency of growth disruptions or physiological stresses in

early childhood. Though the etiology of LEH may have changed across the transition, these differences in causality cannot be identified with certainty.

Enamel hypoplasias in the deciduous teeth from Inamgaon (reported elsewhere) exhibit a clear and unambiguous decline with the adoption of mobile foraging (Lukacs and Walimbe 1998, 2000; Lukacs et al. 2001). The decline in deciduous EH associated with foraging at Inamgaon mirrors the increase in deciduous EH with the rise of agriculture in three prior studies: one in the Levant (Smith et al. 1984) and two in the Ohio River valley (Cassidy 1984; Perzigian et al. 1984).

TOOTH SIZE

Many studies have documented tooth size reduction throughout human evolution (Brace et al. 1987; Christensen 1998; Kieser 1990; Lukacs and Hemphill 1991), but the mechanisms of this widespread pattern of directional change remain controversial (Brace et al. 1991; Calcagno 1989; Calcagno and Gibson 1991; Kieser 1990). Dental reduction, correlated with the adoption and intensification of agriculture, is only one aspect of the generalized gracilization of craniofacial architecture. The reverse transition from farming to foraging should produce an increase in tooth crown size from the EJ to the LJ phase at Inamgaon. Permanent teeth do, in fact, display a consistent and occasionally significant increase in dental dimensions and tooth crown area.

In contrast to the general pattern of dental reduction accompanying the transition from foraging to food production and pottery making, an unusual tooth size increase over a nine-thousand-year period among prehistoric coastal Peruvians has been documented (Scott 1979). In the absence of selective forces for tooth size increase and given evidence of decreasing dental attrition through time, Scott suggests that pleiotropic effects may have been responsible. Increase in tooth size may have been a by-product of craniofacial enlargement in these coastal Peruvian skeletal series, though the causes responsible for change in craniofacial form remain unexplained as well. Few instances of increasing tooth size are known, but one report documents significant size increases in dental dimensions (MD) among the Skolt Lapps, over a period of three hundred years (Kirveskari et al. 1978). Secular trends in tooth size, reported for recent populations worldwide, have been summarized by Harris and colleagues (2001). The most prevalent explanation for rapid, intergenerational increase in tooth size is improvements in diet and health. By analogy, I propose that the primary causes of permanent tooth size increase across the subsistence transition at Inamgaon are the synergistic consequences of improved dietary quality and diversity and improvements in health.

Summary and Conclusions

The Chalcolithic site of Inamgaon in western India (3400–2700 BP) provides evidence for climate change from moist to arid, coupled with a shift from sedentary farming to a seminomadic hunting and foraging lifestyle (circa 3100 BP) reversing the usual trend. Paleopathological research on human biological responses to the adoption and intensification of agriculture has established general trends in human dental characteristics: dental caries rates and enamel hypoplasia increase in frequency, while craniofacial architecture and tooth size declines. My colleagues and I predicted that the "reversed" subsistence transformation at Inamgaon would produce a reversal in human biological responses: a decline in dental caries rates and enamel hypoplasia, along with an increase in tooth size. The results of this study show that permanent teeth exhibit a reduction in caries rates and an increase in tooth size across the subsistence shift, but linear enamel hypoplasia in permanent teeth revealed no consistent or significant change. This result contrasts with the significant reduction in enamel hypoplasia of deciduous canine teeth (LHPC) and a large, though not significant, reduction in the prevalence of IPCH in deciduous teeth. Finally, neither dental caries prevalence nor crown size of deciduous teeth exhibits significant changes or consistent trends from the Early to Late Jorwe phases at Inamgaon. This result may derive from the temporary functional life of the deciduous dentition as a food processor, hence low levels of correlation between environmental change and biological response.

The human biological response to seminomadic hunting and foraging at Inamgaon is most clearly marked in permanent teeth: a decrease in dental caries and an increase in dental dimensions. The absence of significant change in linear enamel hypoplasia is interpreted to reflect similar levels and severity of physiological stress among Early and Late Jorwe peoples, although the stresses were undoubtedly different for farmers and foragers. Deciduous teeth show no clear change in caries rates or tooth size across the transition, but the dramatic decline in deciduous enamel hypoplasias from the Early to the Late Jorwe phase strongly suggests that the diets of pregnant mothers and infants were significantly improved.

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17

Iron-Deficiency Anemia in Early Mongolian Nomads

NARAN BAZARSAD

This chapter describes pathological lesions attributed to iron-deficiency anemia in human skeletal remains from archaeological sites dating from the Bronze and early Iron Age (ninth century BP to first–second century BP) in western and central Mongolia. The study focuses on cribra orbitalia as an indicator of health conditions among nomadic populations from two periods: Chandman (Bronze and early Iron Age) and Hunnu (2209–1907 BP). The collections are from the late Bronze/Iron Age site of Chandman and the Hunnu period site of Borkhan Tolgoi. The collections are curated in the Department of Anthropology, Institute of Archaeology of the Mongolian Academy of Sciences. Both sexes and all age categories are represented in these materials. In the samples from both periods, cribra orbitalia suggestive of iron-deficiency anemia, particularly among juvenile skeletons, occurs in relatively high frequencies.

Geographic, Historic, and Archaeological Background

The Chandman necropolis is located in western Mongolia, in the Chandman Mountains near the Uvs Aimag city of Ulaangom. The Chandmans' position is 49°N, 92°E, and the range has a continental climate, with an average annual temperature of -1°C. The winter (October to April) is cold (with temperatures often dropping to -35°C in January and February), whereas summer (July to September) is pleasant (with temperatures sometimes as high as 22°C). Precipitation is light (300–400 millimeters per year), because of its relatively high altitude, 921 meters above sea level (Tsegmed 1969). From 1972 to 1974, the burial site was wholly excavated by a Mongolian-Russian expedition headed by archaeologists Tseveendorj (1978), Volkov (1972), and Mamanova (1978).

The necropolis of Borkhan Tolgoi is located in central Mongolia, within the valley of the Egiin Gol River, 10 kilometers from its confluence with the Selenge River, a main tributary of Lake Baikal. The valley's position is 49.27°N, 103.30°E, and it has a continental climate, with an average annual temperature of -1°C. The winter (October to April) is cold (with temperatures often dropping to -30°C in January and February), whereas summer (July to Septem-

ber) is pleasant (with temperatures sometimes as high as 22°C). As in western Mongolia, precipitation here is light (300–400 millimeters per year). Because of its relatively high altitude (885 meters above sea level), the valley floor is covered with snow from mid-November to April, and ice thickness on the Selenge reaches 1.8 meters during this period (Tsegmed 1969). From 1997 to 2001, the burial site was wholly excavated by a French-Mongolian expedition, under the sponsorship of UNESCO, headed by archaeologists Turbat and colleagues (2003) and Sheskar.

HISTORICAL CHARACTERISTICS OF THE BRONZE AND EARLY IRON AGE

From the end of the Neolithic period, the forefathers of the Mongols gradually progressed to the production of bronze implements. The earliest metal implements thus far found date to 3300–2700 BP. Numerous bronze implements, various decorations, and household utensils have been discovered in many parts of Mongolia. Rock pictures painted in red have been found to date to the Bronze Age and are typical only of this region. The rock pictures also show stylized animals and human figures standing hand-in-hand with eagles. Along with stone cist graves, "deer stones" are also widely found in Mongolia. The latter are upright stone slabs decorated with stylized pictures of running deer and finely engraved drawings of knives, daggers, bows, and arrows. The people represented by the Chandman burials were of heterogeneous makeup, involving a melange of Europoid and Mongoloid components (Handsuren 1969; Tot and Firshtein 1971; Sukhbaatar 1971).

HISTORICAL BACKGROUND OF THE HUNNU EMPIRE

By 2500 to 2400 BP, a union of two tribes, Hunnu and Dümhü, had formed in Central Asia. The latest historical and biological research suggests that at least some elements of the Hunnu tribal union were ancient Mongols (Batsuuri 1986). The peak of the power of the Iron Age Hunnu tribal union was circa 2300 BP, when the powerful empire that subsequently played a major role in the social and political history of Eurasian nomadic tribes took shape.

The Hunnu tribes met their needs for food and clothing primarily from livestock: hides, hair, meat, milk, and *airag* (fermented mare's milk). The Hunnus are known to have made different kinds of pottery, manually or on a potter's wheel, and to have created jewelry out of gold, silver, and precious stones. They also practiced spinning and weaving. The historical evidence suggests that livestock raising, or pastoralism, developed largely because of Mongolia's extensive grassland—the harsh, dry climate makes most forms of agriculture impractical. The Hunnus also traded with their settled neighbors in China, eastern Turkestan, and Middle Asia for agricultural products, including rice,

wheat, and some fruit products, handicrafts, and jewelry. The mixed diet provided a wide range of micronutrients.

Beginning in 2100 BP, the Hunnus also began to cultivate land. However, because of trade relationship that often failed, the Hunnus became warriors of the steppes, and in the aftermath of their conquests, they forced prisoners of war to work on the land (Sukhbaatar 1980).

Excavations of the sites of ancient Hunnu towns have disclosed complex defensive structures, semisubterranean dwelling pits with heating appliances, remains of workshops, crop-storage houses, iron works, and various kinds of cast-iron ware.

However, the mighty empire of the nomads did not last long. After a fierce internal struggle, in AD 53–55 the empire broke up into Southern and Northern Hunnu. In AD 93 the Northern Hunnus ceased to exist as an independent state: some 500,000 of them joined the Xian'pi tribe and assumed that tribal name. Some of the Northern Hunnus drifted away from their native territory to the Caspian steppes and moved on farther west to the Danube-Carpathian valleys, where they formed a sizeable nomadic state under the leadership of Attila.

Paleodemographic Background

Mamanova (1978) suggests that the average age at death at Chandman was 20–30 years old: for adult males, 37.6 years old; for females, 36.3. Warfare and childbirth are implicated in the relatively short life span of adults, respectively. The peak of mortality among children occurred at the time of weaning because of infection and intestinal diseases.

The paleodemographic aspects of the Hunnu skeletal sample suggest high female mortality during the age ranges 20–29 and 40–49, with a decline at ages 30–39. Few individuals were found in the 50–60 age category. On the basis of this pathological examination, I would suggest that the reasons for this mortality profile in female cases are pregnancy, menstruation, hemorrhage, and iron-deficiency anemia. Likewise, the difficult nomadic lifestyle, with an irregular nutritional regime, and a relatively high rate of infectious diseases would likely have been causative factors in this as well.

Among males, average mortality increases sharply in the decade representing ages 20–29 but increases at a slower rate between ages 30 and 60. Some sexual division of social roles, such as male participation in war but the absence of female hormonal issues, may help explain the different patterns of the sexes.

Materials and Methods

Two predominant series can be considered as the core of this study: (1) the western Mongolian Chandman material is of Bronze and Iron Age and consists of the remains of approximately 108 individuals represented by generally complete individuals or by crania only; (2) the Egiin Gol Hunnu period sample (2209–1900 BP) from central northern Mongolia represents approximately 72 skeletal individuals and 71 individuals represented by skulls only.

These materials, housed in the collections of the Department of Anthropology, Institute of Archaeology of the Mongolian Academy of Sciences, were examined macroscopically for the evaluation of pathological data. Traditional methods (Brothwell 1981; Bass 1995; Goodman, Martin et al. 1984; Ortner and Putschar 1985) were used to determine sex, age, and pathological cases from the assembled crania.

Results and Discussion

Of the 108 individual crania from the Chandman nomadic population from the Bronze and Iron Ages, cribra orbitalia (CO) was observed on 31 individuals (28.7 percent). Of these, 15 are male (23.4 percent of the total male population), 10 are female (27.8 percent of the female population), and 6 are juvenile (75 percent of the juvenile population). The total adult population displays a 24.5 rate of CO, but among older adults, the rate is only 17.5 percent, probably suggesting that anemia contributed to the (relatively) early deaths of afflicted adults. Clearly, CO occurs in a higher percentage of females than males and at a much higher rate in juveniles.

The distribution of CO in human remains from the Hunnu period Borkhan Tolgoi site in the Egiin Gol valley is as follows: of the 71 individual crania from the site, 11 individuals (15.5 percent) displayed this pathology. Of these, 2 are male (5.3 percent of all males), 5 are female (29.4 percent of all females), and 4 are juveniles (25.0 percent of all children). Clearly, overall rates of CO are lower in the later populations. Again, females and children display higher rates than do males. It is noteworthy that frequencies among males and children have declined significantly, while those of females have remained approximately the same.

Although samples, particularly at the later site, are very small, the distribution of CO in the Chandman and Borkhan Tolgoi samples suggests that in both periods there is a sex-based difference in general health status. Higher rates of CO in women may indicate lesser health status or perhaps greater survival of women with CO into adulthood. The very high rates of CO in juveniles, in comparison to adults, suggest that either many cases of childhood CO heal

to the point of obliteration with advancing age or else CO is strongly associated with early death. It is not clear whether CO represents poor diet or high parasite loads. It may reflect protein deficiencies in the weaning process from breastfeeding to solid food, with a likely change from mother's milk to goat milk. However, as Stuart-Macadam (1991, 1992b) suggests, infectious disease is also a major etiological factor in the development of iron-deficiency anemia. Excessive blood loss through injury may also have been a factor, primarily among males. Paleopathological studies of the Chandman series do suggest injuries associated with warfare. However, in the Hunnu series, the minor traumas encountered are more consistent with a daily living situation rather than conditions suggesting armed conflict (despite the reported violent history of the period), perhaps explaining the dramatic decline in the frequency of CO in the later site (Naran 2004).

Summary

Cranial materials from Bronze and Iron Age to Hunnu period samples were examined for paleopathological information suggestive of iron-deficiency anemia in early Mongolian nomad populations.

The distribution of cribra orbitalia in the Chandman and Borkhan Tolgoi samples suggests that in both the Bronze Age and the Hunnu period sites there is a sex-based difference in general health status. Overall, CO declines in the later period despite the addition of agricultural products to the diet. For both periods, CO was found to be much more common in subadults than in adults. The lower incidence among adults may be attributed to one of two explanations: either many cases of childhood cribra orbitalia heal with advancing age or else CO leads to an early death. The relatively high frequencies of cribra orbitalia among the Mongolian Chandman children may be explained in the context of living stress induced by the process of learning and mastering new territory.

The archaeological, ethnographical, environmental, and subsistence evidence suggests that Hunnu populations (exemplified by the skeletal series from Borkhan Tolgoi) were healthier than Chandman populations.

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Diet and Health in the Neolithic of the Wei and Middle Yellow River Basins, Northern China

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This chapter reports on trends in human health and morbidity in northern China during a time frame lasting from about 9,000 to 1,800 years ago. Our analysis is based on the frequencies of pertinent skeletal markers detected on the remains of individuals from collections excavated at sites dating to the Peiligang, Yangshao, Longshan, and Dynastic periods. The chronological position accorded each of the pertinent sites is based on interpretation of radiocarbon dates, stratigraphy, ceramic sequences, and, in the case of the Dynastic period material, on textual evidence (see Table 18.1).

Peiligang

Peiligang (circa 9000–7000 BP) is represented in this study by a skeletal series from Jiahu, in central Henan. At 5.5 hectares, Jiahu was a relatively large settlement for its time: a more typical size for Peiligang settlements was 1 to 2 hectares (Liu 2004: 74). Jiahu was partitioned into several residential clusters, each with a specially defined cemetery (Henan Institute 1989; Liu 2004: 126). The site is well known for its bone flutes (Zhang et al. 2004), inscriptions on tortoise shell (Xueqin et al. 2003), and a sequence of rice phytoliths and grains documenting the domestication of this important food plant (Chen et al. 1995a, 1995b).

Yangshao

The majority of the skeletal individuals examined for this study were collected at sites pertaining to Yangshao, a Neolithic culture group that dominated the region drained by the middle Yellow River. Yangshao is conventionally divided into Early, or Banpo (circa 6950–6000 BP), Middle, or Miaodigou (circa 6000–5500 BP), and Late, or Xiwang (circa 5500–5000 BP), although some local chronologies vary slightly from these ranges (Dai 1998; Zhang and Qiao 1992). Our Early Yangshao samples came from four sites in the central and

Table 18.1. Chronology and Location of the Pertinent Archaeological Sites

Site	County	Province	Cultural Phase	Occupation Interval[a]	Radiocarbon Years BP Age[b]
Jiahu	Wuyang	Henan	Peiligang	9000–7000	8220–7490
Banpo	Xi'an city	Shaanxi	Early Yangshao	6800–6300	6285–5170
Beiliu	Weinan	Shaanxi	Early Yangshao	6800–6200	6570–6210
Jiangzhai I	Lintong	Shaanxi	Early Yangshao	6900–6400	6180–5465
Jiangzhai II	Lintong	Shaanxi	Early Yangshao	6400–6000	5200–4590
Shijia	Weinan	Shaanxi	Early Yangshao	6300–6000	5200–4800
Guanjia	Luoyang	Henan	Middle Yangshao	6000–5500	
Xipo	Zhudingyuan	Henan	Middle Yangshao	6000–5500	
Meishan	Linru (Ruzhou)	Henan	Late Longshan	4500–4000	
Mengzhuang	Huixian	Henan	Late Longshan	4500–4000	
Kangjia	Lintong	Shaanxi	Han Dynasty	2200–1800	

[a] The approximate time period of pertinent human occupation in calendar years ago based on calibrated radiocarbon dates, stratigraphy, ceramic sequences, and, where applicable, historical (textual) evidence, as reported in Liu (2004), Ma (2005), Henan Provincial Institute of Cultural Relics and Archaeology (2003), and XBM (1988).
[b] The cumulative range of available uncalibrated dates in radiocarbon years at ±2 standard deviations based on IA CASS 1991 and Zhang et al. 2004.

eastern parts of Shaanxi province: Banpo, Beiliu, Jiangzhai, and Shijia (Figure 18.1, Table 18.1).

Shijia is situated on the western bank of the Qiu River, twelve kilometers south of the Wei River, in eastern Shaanxi (Xi'an Banpo Museum 1978). The style of material culture excavated from the site suggests that it was occupied toward the end of the Early Yangshao (Gong 1988). Beiliu, located just one kilometer south of Shijia, is a multicomponent site, representing both the early and middle phases of the Early Yangshao.

Jiangzhai is located south of the Wei River, on the northern bank of the Linho River (Xi'an Banpo Museum 1988). Jiangzhai had a settled area of approximately five hectares, demarcated by a substantial ditch (Xi'an Banpo Museum 1988). The living community consisted of more than a hundred houses, which surrounded a central plaza encompassing circular structures interpreted as animal pens. There were two discrete areas of occupation, each representing a different time period: Jiangzhai I (earliest Yangshao) and Jiangzhai II. Burials from Jiangzhai I were distributed in a number of clusters outside the ditch (Xi'an Banpo Museum 1988). Jiangzhai II burials were found mainly in the central area of the site.

Middle Yangshao individuals examined for this study came from Xipo and Guanjia, both in western Henan. During Middle Yangshao, the overall number and size of settlements increased, the Yangshao sphere of influence expanded, and there was greater stylistic uniformity in material culture (Dai 1998; Ma

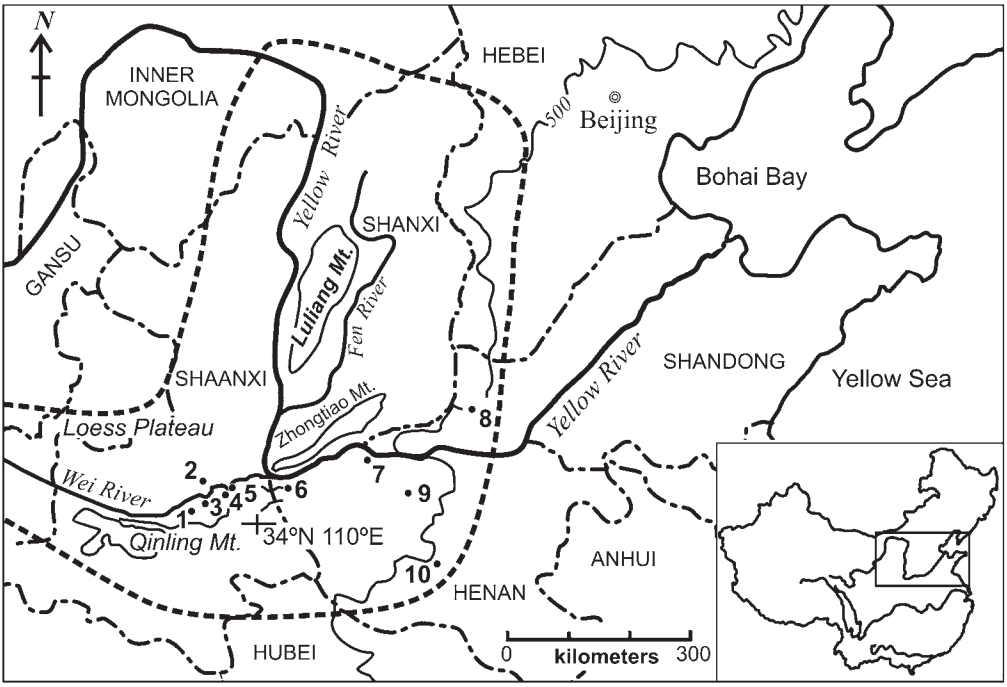

Figure 18.1. The study area. Dashed line marks approximate boundaries of the region of China in which Yangshao material culture has been recognized. *1,* Banpo; *2,* Kangjia; *3,* Jiangzhai; *4,* Beiliu; *5,* Shijia; *6,* Xipo; *7,* Guanjia; *8,* Mengzhuang; *9,* Meishan; *10,* Jiahu.

2003; Yan 1982b; Su 1999). The onset of social complexity was evidenced by construction of the earliest monumental edifices and development of a three-tier settlement-size hierarchy, along with marked inequality in the burial treatment of individuals (Ma 2003, 2005; Ma et al. 2006; Dai 1998; Yan 1982b; Su 1999).

Xipo is located in the upper Sha River valley, about three kilometers north of the Qinling Mountains, in the western corner of Henan (Ma 2005; Ma et al. 2005, 2006). Xipo may have been a regional center. It was a relatively large settlement (forty hectares), surrounded by a moat, and with an estimated population of 640–900 people (Ma 2003: 85). There was a three-level size hierarchy among the houses, as well as several larger labor-intensive structures; the biggest may have served as a gathering place for ritual or public functions (Ma 2003: 100). A cemetery outside the moat yielded 22 burials, all single interments. Associated grave goods indicate considerable differences in wealth or status.

Guanjia, the other Middle Yangshao site, was a smaller settlement (nine hectares). It is located along a narrow terrace on the south bank of the Yellow River, about seventy kilometers northeast of Mianchi (Fan 2000). The major occupation at Guanjia was contemporaneous with that at Xipo, but Peiligang and Early Dynastic remains are also present. Ditches demarcate the western and southern limits of the site, where it is not bounded by the Yellow River. Most of the burials uncovered had no associated artifacts (Fan 2000).

During Late Yangshao, an overall population increase in the middle valley was accompanied by the development of fortified towns with monumental public architecture (Liu 2004: 85–86). No Late Yangshao human remains were made available for this study.

Longshan

By about 5000 BP, the Yangshao cultural pattern had been succeeded by Longshan, marked by polished gray or black pottery, as well as a shift in settlement density and distribution. In much of the lowlands, population increased dramatically, while some of the adjacent uplands experienced a decline in population (Liu 2004: 27). Longshan burials are relatively rare, suggesting that some alternative postmortem treatment was being practiced. Longshan individuals examined for this study came from burials dating to approximately 4500–4000 BP at two sites in Henan: Mengzhuang and Meishan.

Meishan is located northwest of modern Ruzhou (Henan Institute 1991). Mengzhuang, in northern Henan, is on the north bank of the Wei River, near Huixian, in the southern foothills of the Taihang Mountains. It is a multicomponent site, with evidence for continuous occupation from the early Neolithic through the Dynastic period; only Longshan skeletons are considered here. During the Longshan period, the settlement was surrounded by walls 15.5 meters thick (Henan Institute 2003).

Dynastic Period

Han Dynasty individuals examined for this study came from Kangjia, in Shaanxi, north of the Wei River, dating to circa 2200–1800 BP (Liu 1994). Supplementary data are provided for burials from Kayue, in Qinghai province, west of our primary study area (Zhang and Han 1998), and a commingled Western Zhou collection (circa 3100–2850 BP) of uncertain provenience (Pechenkina et al. 2002). All three samples represent a time period characterized by further increase in human population density, as well as increasing social stratification.

Subsistence

Trace element and stable isotope analysis of human bones from Jiahu indicate that there was continuing use of wild resources and cultivated cereals throughout the Peiligang sequence (Hu 2002, Hu et al. 2006). The relatively high concentration of ^{15}N isotopes ($\delta^{15}N$ ranges from 7.21 to 10.46‰) indicates that the human diet at Jiahu also included a substantial proportion of animal products. Millet may have been a minor dietary constituent, as suggested by the $\delta^{13}C$ spacing between collagen and apatite. However, the low $\delta^{13}C$ of bone collagen (from -20.87 to -18.77‰) indicates a C3 based diet, thus suggesting rice as the staple cereal at Jiahu (Hu et al. 2006).

Alterations in subsistence practices in Shaanxi and Henan provinces during the Neolithic included increasing dependence on domesticated millet and pig husbandry (Yan 1992; Yuan and Flad 2002). Rice was grown, but in small quantities (Wei et al. 2001; Yan 1982a; Luoyang Museum 1981; An 1984). Wheat was apparently introduced into the area toward the end of the Longshan period (circa 4300 BP) (Crawford et al. 2005) and eventually replaced millet as the principal grain during the Dynastic period. Domesticated sheep and/or goats (*Ovis/Capra*) become evident during the later part of Longshan, sometime between about 4500 and 4000 BP (Zhou 1984; Liu 1994; Huang 1996; Yuan and Flad 2002). At least in western Shaanxi, fishing and foraging retained their importance throughout the Neolithic, to a far greater degree than in Henan (Yuan and Flad 2002).

Stable isotope analysis of fifteen human bone samples from the Yangshao sites of Jiangzhai and Shijia yielded carbon isotope values typical of farmers practicing C_4 agriculture (Pechenkina et al. 2005). Average collagen carbon isotope values ($\delta^{13}C$‰) for Jiangzhai I were -9.3‰ (n=2), -10.5‰ (n=3) for Jiangzhai II, and -10.0‰ (n=9) for Shijia, suggesting that millet constituted 75–85 percent of the diet (Pechenkina et al. 2005). Nitrogen isotope values ($\delta^{15}N$‰) were highest for Jiangzhai I (9.01‰) and lower for samples from the more recent occupations at Jiangzhai II (8.63‰) and Shijia (8.10‰), suggesting some reduction in the consumption of animal products through time. A single specimen of human bone from the Banpo series had more negative ^{13}C and somewhat higher ^{15}N values (-15.00‰ and 9.05‰, respectively), indicating a greater proportion of wild foods in the diet of that individual.

Although no stable isotope estimates are available for human bone dating to Middle Yangshao, analysis of pig and dog bones from Xipo indicates that millet contributed up to 90 percent of their diet (Pechenkina et al. 2005). It seems likely that humans from Xipo also depended on millet for their subsistence. Further intensification of millet agriculture during the Longshan period is also

Table 18.2. Dietary Composition of Commonly Grown Cereals

	Cal.	Prot. (g)	Carb. (g)	Iron (mg)	B1 Thiamin (mg)	B2 Riboflavin (mg)	B3 Niacin (mg)	C Ascorbic Acid (mg)	Protein Score (%)[a]
RDA				48–59	10–18	1.4–1.8	1.1–1.5	14–20	40–60
Cereal									
Barley	327	10.5	71.8	6	0.31	0.1	5.2	0	62 [Ly]
Buckwheat	336	10.3	73.8	3	0.36	0.18	2	0	89 [Le]
Maize	306	9.1	71.7	2.8	0.29	0.11	2.1	0	63 [Ly]
Millets									
Setaria sp.	341	9.5	74.7	5.5	0.43	0.12	2.2	0	34 [Ly]
Panicum sp.	326	12.7	66.5	3.5	0.4	0.1	4	0	41 [Ly]
Sorghum sp.	342	10	72.7	3.8	0.33	0.18	3.9	0	37–48 [Ly]
Rice	341	5.8	73.4	1.4	0.33	0.06	5.6	0	60–77 [Ly]
Rye	334	12.8	70.4	3.0	0.47	0.20	1.7	0	82 [Th]
Wheat	332	11.6	72.1	3.3	0.37	0.12	4.6	0	57 [Ly]

Source: FAO 1972.

Note: Dietary composition is based on 100 grams of edible portion. Cal. = dietary calories; Prot. = protein; Carb. = carbohydrates; Le = leucine; Ly = lysine; Th = threonine.

[a] Protein score is based on presence of essential amino acids, listed in brackets.

[b] RDA is given as grams or milligrams, as indicated.

suggested by stable isotope analysis of human bone from Shaanxi (Cai and Qui 1984).

Dietary deficiencies associated with reliance on specific cereals have been observed in a number of studies (for example, Cohen and Armelagos 1984; Larsen 1995; Papathanasiou 2005); these can also be predicted from the inadequate nutrient content of such foods (Food and Agriculture Organization 1972; Drake 1989; Table 18.2). Most cereals lack vitamin C and are low in niacin (B_3). Among the most niacin-deficient cereals are *Setaria* millet, buckwheat, rice, and maize. Although millets have a relatively high iron content, absorption of nonheme iron from plant sources is very inefficient and is further impeded by the lack of vitamin C (Hallberg and Hulthén 2000).

With the exception of rye and buckwheat, almost all cereals contain minimal levels of largely incomplete protein. Millets are among the poorest sources of protein; they are particularly deficient in lysine, the lack of which can lead to a number of physiological disorders, including anemia, anorexia, growth arrest, weight loss, and low protein turnover, as well as collagen and myosin structural anomalies (Harper et al. 1970; Gietzen 1993; Cree and Schalch 1985; Astrom and Decken 1983).

Oral Health

The Peiligang skeletal series from Jiahu, although substantial, is practically devoid of teeth, except for three fragmentary maxillae and two mandibles; most teeth were lost postmortem. A number of conditions, including abscesses—one of them penetrating a paranasal sinus—the loss of alveolar height, and the obliteration of dental sockets, all suggest persistent oral infections and relatively early tooth loss. Of forty available disassociated teeth, five had carious lesions.

There is marked variation in all indicators of oral health among individuals from the Yangshao sites. In Early Yangshao collections from Shaanxi, frequencies of carious lesions were generally low, varying from 6 percent for Jiangzhai II to 29 percent for Beiliu (Table 18.3). All caries detected were on molars and premolars. The lesions were usually small, affecting only one surface of a single tooth, without resulting in abscesses. The average number of carious lesions per adult dentition was consistently less than one, varying from 0.25 to 0.57 (Table 18.4). The elevated frequency of caries in dentitions from Beiliu probably stems from the advanced age of all individuals in that sample.

Table 18.3. Frequencies of Individuals with Specific Pathological Conditions Reflecting Oral Health

Site	Post. Caries f. [*N*][a]	Ant. Caries f. [*N*]	Root Caries f. [*N*]	Abscess f. [*N*]	AMTL f. [*N*]	Calculus Accretion f. [*N*]
Yangshao						
Beiliu	.29 [7]	.00 [3]	.00 [3]	.00 [7]	1.00 [7]	.43 [7]
Jiangzhai I	.15 [13]	.00 [11]	.00 [11]	.09 [11]	.17 [13]	.77 [13]
Jiangzhai II	.06 [17]	.00 [20]	.00 [20]	.00 [20]	.12 [17]	.35 [17]
Shijia	.21 [28]	.00 [21]	.00 [21]	.04 [21]	.61 [28]	.46 [28]
Guanjia	.75 [24]	.25 [24]	.13 [24]	.38 [24]	.46 [24]	.62 [21]
Xipo	.79 [19]	.17 [18]	.11 [19]	.47 [19]	.63 [19]	.42 [19]
Longshan						
Meishan	.71 [7]	.40 [5]	.43 [7]	.29 [7]	.29 [7]	.57 [7]
Mengzhuang	.50 [6]	.00 [5]	.00 [5]	.00 [5]	.00 [5]	.83 [6]
Dynastic						
Kangjia	.62 [13]	.30 [10]	.30 [10]	.31 [13]	.77 [13]	.23 [13]
Western Zhou	.04 [23]	.00 [23]	.00 [23]	.00 [23]	.17 [23]	.00 [23][a]
Kayue[b]	.33 [12]	--	--	.25 [12]	.33 [12]	.16 [12]

Note: *N* = number of dental sets examined; f. = frequency of incidence; Post. = posterior teeth (molars and premolars); Ant. = anterior teeth (incisors and canines); AMTL = antemortem tooth loss.

[a] Absence of calculus accretions is probably the consequence of overall poor preservation.

[b] Based on Zhang 1993.

Table 18.4. Number of Pathological Conditions per Adult Dentition

Site	Caries Count [*N*]	Root Abscess Count [*N*]	Antemortem Tooth Loss Count [*N*]	Calculus Accretion Count [*N*]
Yangshao				
Beiliu	0.57 [7]	0.00 [3]	6.43 [7]	0.00 [7]
Jiangzhai I	0.46 [13]	0.00 [11]	1.38 [13]	0.00 [11]
Jiangzhai II	0.29 [17]	0.00 [20]	0.76 [17]	0.00 [20]
Shijia	0.25 [28]	0.05 [21]	0.71 [21]	0.00 [21]
Guanjia	3.04 [24]	0.83 [24]	2.38 [24]	0.38 [24]
Xipo	2.10 [19]	1.00 [19]	4.79 [19]	0.47 [19]
Longshan				
Meishan	3.14 [7]	0.57 [5]	1.14 [7]	0.29 [7]
Mengzhuang	0.83 [6]	0.40 [5]	0.00 [5]	0.00 [5]
Dynastic				
Kangjia	3.23 [13]	0.30 [10]	0.30 [10]	0.31 [13]
Western Zhou	0.65 [23]	0.00 [23]	0.00 [23]	0.00 [23]

Note: *N* = number of dental sets examined.

The dental health of individuals from the Middle Yangshao sites of Guanjia and Xipo was considerably worse. Large multiple caries were frequent on anterior as well as posterior teeth (for the latter, 75 percent and 79 percent of individuals, respectively, with at least one carious lesion) and were often associated with abscesses. Antemortem tooth loss was high (Figure 18.2, B).

Poor oral health is also evident in collections from the Longshan site of Meishan, as well as the Dynastic period series from Kangjia (Figure 18.2, A; Tables 18.3–18.4). However, Longshan dentitions from Mengzhuang were affected by caries to a considerably lesser degree than those from contemporary Meishan. The commingled Western Zhou collection shows very low frequencies of both caries and abscesses.

Rapid dental wear was typical of individuals from both the Early and Middle Yangshao periods, although there was considerable variation within sample groups. The teeth of older individuals were frequently worn to below the cemento-enamel junction and there was traumatic pulp exposure, a degree of tooth wear that may reflect the use of teeth as tools. Enamel chipping was also common. Lingual surface attrition of the maxillary anterior teeth (LSAMAT) was found on Jiangzhai dentitions (Pechenkina et al. 2002). On individuals from Xipo and Jiahu, some mandibular incisors were worn to a greater degree than molars and premolars (Figure 18.2, C–D).

Mandibular and maxillary tori and exostoses were present in all of the Yangshao skeletal collections, but with considerable variation in frequency. These conditions were more common at Early Yangshao sites, Jiangzhai and Shijia, than at those of Middle Yangshao, Guanjia and Xipo (Table 18.5). The

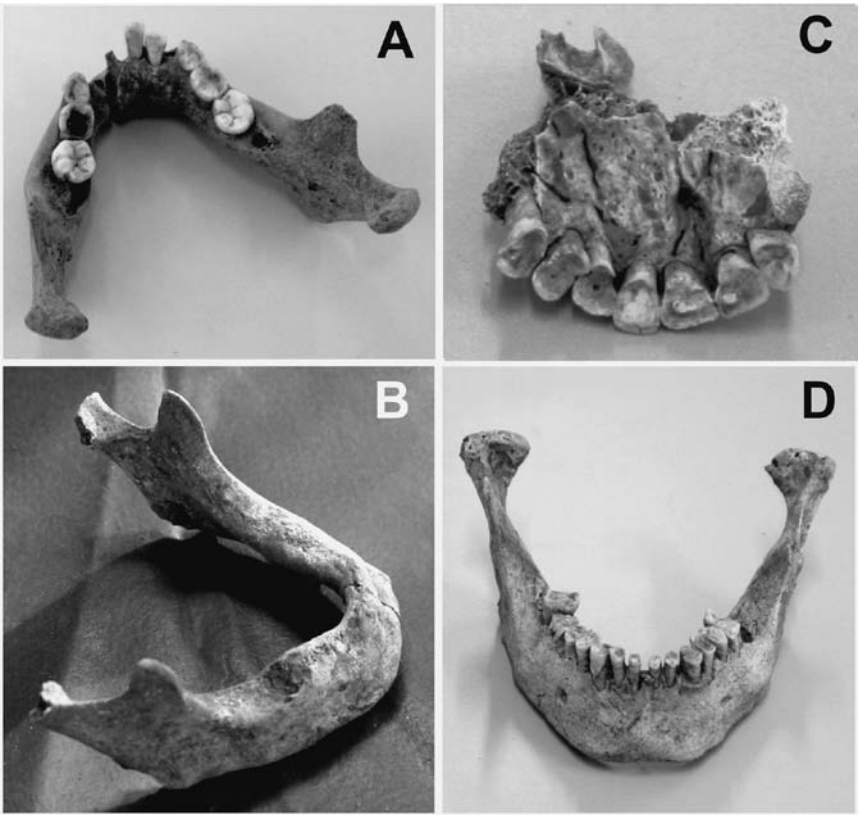

Figure 18.2. Oral health during the Chinese Neolithic. *A,* carious lesion on a deciduous molar (Meishan MT20); *B,* an edentulous mandible (Guanjia M26); *C,* lingual attrition of the anterior teeth (Xipo M14); *D,* severe anterior wear and osteoarthritis of the temporomandibular joint (Xipo M21).

frequency of exostoses on the mandible and maxilla was particularly high on dental sets from Shijia (28 percent for mandibular tori; 54 percent for maxillary exostosis). The frequency of mandibular tori for the Shijia sample is comparable to that observed for other populations from East Asia (Dodo and Ishida 1987; Kerdpon and Sirirungrojying 1999) but lower than that reported for circumpolar populations (Zubov 1973; Steffensen 1969; Dodo and Ishida 1987).

Osteoarthritis of the temporomandibular joint was common in all of the collections studied, except for those of the Dynastic period. The highest frequencies of degenerative lesions on the TMJ were observed for Xipo and Beiliu dentitions (82 percent and 67 percent, respectively). The preponderance of temporomandibular disorders in these collections can be linked to antemor-

Table 18.5. Frequencies of Mandibular and Maxillar Torii and Exostoses and Osteoarthritis of the TMJ

Site	Mandibular Torus f. [*N*]	Maxillar Exostosis f. [*N*]	Temporomandibular Disorders f. [*N*]
Yangshao			
Beiliu	.17 [6]	.50 [6]	.67 [6]
Jiangzhai I	.00 [5]	.07 [15]	.25 [4]
Jiangzhai II	.15 [13]	.47 [17]	.13 [16]
Shijia	.28 [34]	.54 [35]	.52 [33]
Guanjia	.09 [22]	.10 [20]	.18 [22]
Xipo	.19 [16]	.12 [17]	.82 [17]
Longshan			
Meishan	.00 [5]	.00 [6]	.60 [5]
Mengzhuang	.00 [5]	.40 [5]	.17 [6]
Dynastic			
Kangjia	.00 [9]	.00 [10]	.22 [9]
Western Zhou	.00 [23]	.00 [15]	.22 [23]
Kayue[a]	—	.16 [12]	—

Note: *N* = number of observable elements; f. = frequency of affected elements.
[a] Based on Zhang 1993.

tem tooth loss and/or stresses related to use of the anterior teeth as tools (Figure 18.2, D; Table 18.5).

Oral health data are available from the literature for a few other ancient Chinese skeletal collections (for example, Zhang and Han 1998; Zhang 1993). Six Late Neolithic skulls from Yuchisi, in Anhui province, north of the Huai River, which date to approximately 4800–4500 BP (Zhang and Han 1998; Wang 1998), evidenced no carious lesions, a state of oral health similar to that of the Jiangzhai and Shijia Early Yangshao populations. However, antemortem tooth loss was high at Yuchisi, with three out of six dentitions missing several teeth. Occlusal wear was concave and mild to moderate, reflecting diets dominated by cereals (Smith 1984). Both rice and millet phytoliths have been recovered at the site (Wang 1998).

Twelve adult skulls also showing poor dental health stem from a site of the Shang Dynasty–era Kayue culture, in Lijishan County, Qinghai (Zhang 1993). Antemortem tooth loss was frequent, with four of the twelve skulls missing at least one tooth. Large cavities with multiple root abscesses on the labial sides were present on the alveoli of three of the female skulls.

Nonspecific Indicators of Stress

Table 18.6 summarizes the occurrence of nonspecific indicators of stress in all of the skeletal collections utilized in this study. There are large differences in

Table 18.6. Nonspecific Indicators of Physiological Stress

Age Category/ Site	Porosity of Cranial Vault f. [*N*]	Moderate/ Severe PH f. [*N*]	Cribra Orbitalia f. [*N*]	Sphenoid Porosity f. [*N*]	Linear Enamel Hypoplasia f. [*N*]
Peiligang adult					
Jiahu	0.46 [37]	0.19 [37]	0.25 [28]	—	—
Yangshao adult					
Beiliu	0.00 [6]	0.00 [6]	0.00 [6]	0.00 [5]	—
Jiangzhai I	0.11 [9]	0.00 [9]	0.33 [9]	0.11 [9]	0.57 [14]
Jiangzhai II	0.16 [19]	0.00 [19]	0.11 [19]	0.05 [19]	0.27 [11]
Shijia	0.23 [39]	0.08 [39]	0.03 [38]	0.15 [39]	0.09 [22]
Guanjia	0.33 [21]	0.14 [21]	0.10 [20]	0.00 [4]	0.76 [17]
Xipo	0.30 [17]	0.12 [17]	0.06 [16]	0.00 [11]	0.33 [12]
Yangshao nonadult					
Jiangzhai	0.00 [6]	0.00 [6]	0.17 [6]	0.20 [5]	—
Shijia	0.14 [7]	0.00 [7]	0.20 [5]	0.00 [5]	—
Guanjia	0.25 [4]	0.25 [4]	0.25 [4]	—	1.00 [3]
Longshan					
Meishan adults	0.83 [6]	0.50 [6]	0.50 [6]	—	0.60 [5]
Meishan juv.	0.00 [7]	0.00 [7]	0.43 [7]	—	0.33 [3]
Mengzhuang	0.14 [7]	0.14 [7]	0.40 [5]	—	1.00 [4]
Dynastic adult					
Kangjia	0.56 [9]	0.33 [9]	0.44 [9]	0.00 [9]	0.80 [10]
Western Zhou	0.44 [18]	0.22 [18]	0.56 [18]	0.00 [18]	—

Note: *N* = number of observable elements; f. = frequency of affected elements.

the prevalence of nonspecific indicators of stress. Because the number of individuals is relatively small and many are fragmentary, these differences could be an artifact of sampling error. Nevertheless, certain noticeable trends are suggestive.

We distinguish simple porosity of the cranial vault from porotic hyperostosis (PH) or macroporosity with clear hyperostosis. Porous lesions of the parietal, frontal, and occipital bones can result from many different conditions, including scurvy, osteoporosis, and inflammation, and are sometimes pseudopathological (Grupe 1995; Wapler et al. 2004; Ortner et al. 1999). Porotic hyperostosis or macroporosity of the cranial vault associated with diploe expansion, as well as hyperostosis of the orbital roof or cribra orbitalia (CO), both may suggest chronic anemia during early childhood (Ortner and Putschar 1985; Stuart-Macadam 1987a,b, 1989). Porous lesions below the temporal lines on the parietal and sphenoid bones probably indicate scurvy (Ortner et al. 1999; Ortner et al. 2001; Brickley and Ives 2006). The fragmentary nature of Neolithic Chinese osteological collections limits confident diagnosis as to the source or sources of these lesions.

Porous lesions were common on the crania from Henan, including the Peiligang collection from Jiahu (PH evident on 19 percent of the crania), as well as the Middle Yangshao collections from Xipo (12 percent) and Guanjia (14 percent).

Despite heavy reliance on millet at Jiangzhai and Shijia, as indicated by stable isotope values for human bone, surprisingly low frequencies of porotic hyperostosis were found on adult skulls (PH at Jiangzhai was 0 percent; for Shijia, 8 percent). The frequency and severity of CO and PH were considerably greater in our tiny samples from the subsequent Longshan, Western Zhou, and Han periods (PH for Meishan adults was 50 percent; for the Western Zhou collection, 22 percent; for Kangjia, 33 percent; CO frequencies were even higher). The Longshan collection from Mengzhuang had a modest PH frequency (14 percent) but a high frequency of CO (40 percent).

Linear enamel hypoplasia (LEH) was common in all of the collections, with the exception of that from Shijia (9 percent). The highest frequencies of LEH were found on the Mengzhuang, Kangjia, and Guanjia adult dentitions (100 percent, 80 percent, and 76 percent, respectively), as well as among Guanjia nonadults (100 percent). No clear temporal or other trend in such frequencies was detected.

Adult stature, as estimated from long bone lengths, varied substantially among the collections (Table 18.7). The greatest average statures recorded for both sexes were from the early Peiligang collection made at Jiahu (173.7 centimeters for males and 164.5 centimeters for females). Jiahu males appear to have been remarkably tall, even by comparison with modern Chinese males. The average height of 20–year-old males in northern China in 2001 was reported as 171.8 centimeters (Lei et al. 2006). Estimated average statures for all of the Yangshao collections are lower. Longshan and Dynastic period individuals were even smaller.

Sexual dimorphism (the difference between male and female stature, divided by average stature) also showed considerable variation among the collections examined (Table 18.7). The highest degree of sexual dimorphism was found for samples from sites evidencing the heaviest reliance on cooked cereals: Xipo, Meishan, and Kangjia.

Systemic Infection

Few studies have addressed the prevalence of infectious diseases in ancient China. Suzuki and colleagues (2005) examined Bronze Age skeletal collections (N=181) from three sites of the Kayue culture (circa 3000–1500 BP) in Qinghai. Periosteal lesions predominantly affected the tibiae and were observed on the long bones of fifteen individuals. Two postcranial skeletons had lesions typical

Table 18.7. Femur Length and Estimated Stature from Chinese Neolithic Samples

	Femur Length (mm)		**Estimated Stature (cm)[a]**		
Site	Males [*N*]	Females [*N*]	Males	Females	Sexual Dimorphism
Early Neolithic					
Jiahu	470.31±17.4 [32]	428.09±33.8 [21]	173.69	64.49	2.72
Yangshao					
Beiliu	448.00±27.3 [4]	408.84±20.1 [4]	168.89	160.50	2.55
Jiangzhai I	455.87±19.4 [4]	427.85±19.9 [5]	170.58	164.53	1.81
Jiangzhai II	450.73±17.9 [7]	416.90±11.3 [6]	169.46	162.26	2.17
Shijia	447.71±26.0 [14]	410.08±16.5 [10]	169.26	161.11	2.47
Guanjia	440.60±10.9 [5]	413.44±20.7 [9]	167.30	161.46	1.78
Xipo	448.98±24.5 [11]	398.65±23.3 [5]	169.10	158.28	3.31
Longshan					
Meishan	441.8±15.1 [5]	389.6±31.0 [3]	167.56	156.33	3.47
Mengzhuang[b]	438.9±29.2 [9]	418.5±15.0 [4]	166.93	162.55	1.33
Dynastic					
Kangjia	433.4±18.8 [9]	366.8±14.8 [4]	165.76	155.74	3.12
Western Zhou	437.0±18.3 [8]	397.1±24.6 [6]	166.52	157.94	2.64

[a] Stature estimates are based on formulas for Mongoloid males from Trotter and Gleser 1958.
[b] Based on Henan Institute 2003: 546.

of treponemal infection, but no cranial involvement was detected (Suzuki et al. 2005).

Mycobacterial DNA was identified by polymerase chain reaction (PCR) in three of fifteen human skeletons recovered from tombs excavated in Xinjiang-Uigur province in northern China, dating to the Cheshi-Quianguo period, about two thousand years ago. No macroscopic skeletal lesions suggesting tuberculosis were found (Fusegawa et al. 2003). Furthermore, the primers used in the procedure were specific not only for *Mycobacterium tuberculosis* but also for *M. bovis* (Eisenach et al. 1990) and for *M. microti,* which typically infects rodents. Thus, it is not clear whether the DNA found actually was derived from a human-specific strain of *Mycobacterium.*

We found little evidence of chronic systemic infection on the Yangshao skeletons. Periosteal bone formation was associated exclusively with traumatic injury. One subadult skeleton (a 12–14-year-old) from Shijia presented inflammatory lesions on the distal diaphyses of both femora. A radiograph (Figure 18.3, A) revealed pathological subperiosteal and endosteal changes in both femora suggestive of chronic infection. On the same radiograph, transverse lines above the distal epiphyseal plate might reflect multiple growth arrest episodes related to chronic infection.

One Late Longshan skeleton (Meishan M7) had an angular deformity of the spine, resulting from virtually complete resorption of the ninth thoracic vertebral body and partial resorption of the eighth (Figure 18.3, B and C). These

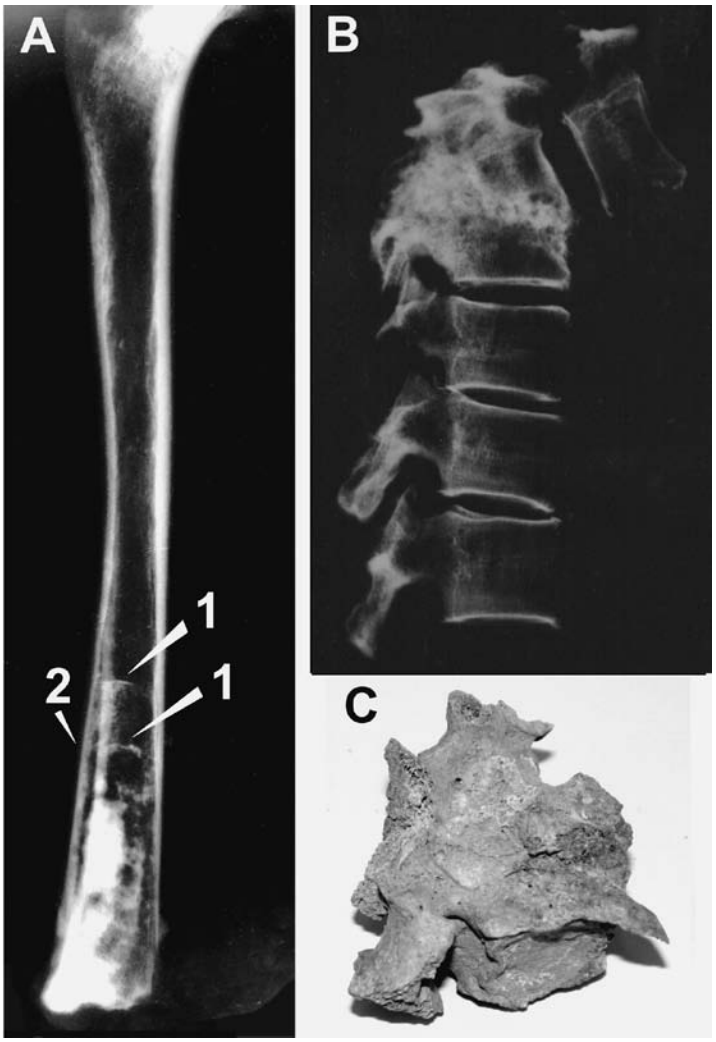

Figure 18.3. Systemic infection in northern China during the Neolithic. *A,* right femur of a 12–14-year-old child (Shijia M43:27): *1,* growth arrest lines; *2,* raised cortices on the distal portion of the femoral diaphyses. *B* and *C,* resorptive lesions on the thoracic vertebrae of Meishan M7; possible tuberculosis spondyloarthropathy.

lesions are consistent with tuberculous spondyloarthropathy, or Pott's disease (Ortner and Putschar 1985). Bone tuberculosis might also have been the cause of a solitary focus of circumscribed macroporosity on the left parietal of the same individual. No other skeletal elements were affected. These findings represent what may be the earliest documented case of bone tuberculosis from East Asia. However, molecular analysis would be needed to exclude other in-

fectious diseases such as brucellosis and blastomycosis as possible causes of those lesions and the associated trauma (Aufderheide and Rodriguez-Martin 1998).

A Han Dynasty adult skeleton from Kangjia had circumscribed periosteal lesions on the long bones, appearing as nodules 3–4 centimeters in diameter on the distal metaphyses and the distal portion of the diaphyses of both tibiae, or as lobules on the proximal metaphyses of the tibiae, fibulae, and femora. Lesions were found on both anterior and posterior surfaces of the leg bones but were especially prominent on the entheses, along the popliteal line, on the medial malleoli, on the gluteal tuberosities of both femora, and along the interosseus crests of the fibulae. Lobular bone formation was also observed on both humeri around the deltoid tuberosities and distal metaphyses. The circumscribed form of these lesions suggests that there were numerous ulcers in the soft tissues overlying the affected bone. These ulcers could have resulted from either a systemic infection or diabetes in an advanced stage.

Traumatic Injury and Violence

A high frequency of cranial trauma was evident from the samples recovered at three of the Yangshao sites in Shaanxi: Jiangzhai (27.6 percent), Shijia (18.9 percent), and Beiliu (16.6 percent, one out of six skulls). Many of these traumatic injuries apparently reflect interpersonal violence (Pechenkina 2002, see also Jackes 2004 for detailed discussion of the Jiangzhai fractures).

One skull (M18) from Beiliu, a probable male, had perimortem cut marks on the forehead that could have resulted from scalping (Figure 18.4, A). A perimortem depression fracture of the frontal bone on a female skull from Jiangzhai could have been produced by a rounded stone or club (Figure 18.4, B). A Jiangzhai male (M112:13) had a healed compression fracture of the left zygomatic (Figure 18.4, C), which could have resulted from a blow delivered using a blunt instrument held in the right hand by an opponent directly facing the victim. Large areas of bone depression, surrounded by oppositional bone and macroporosity, were found on the parietals of a Jiangzhai male (M202:36A) and a Shijia probable female (M28:19). These depressions likely represent healed and remodeled blunt fractures, similar to the perimortem compression fractures described above. There was also a healed and remodeled infraction of the frontal bone on a male skull (M27:29) from Shijia (Figure 18.4, D).

Postcranial bones are underrepresented in the Jiangzhai and Shijia collections. One Jiangzhai male (M150) had a dislocated fracture of the left ulna, which could have been a parrying injury, but also might have resulted from a fall (Lovell 1997). A female from Beiliu (M10) had healed fractures on the distal portion of the left radius and ulna that very likely resulted from extending

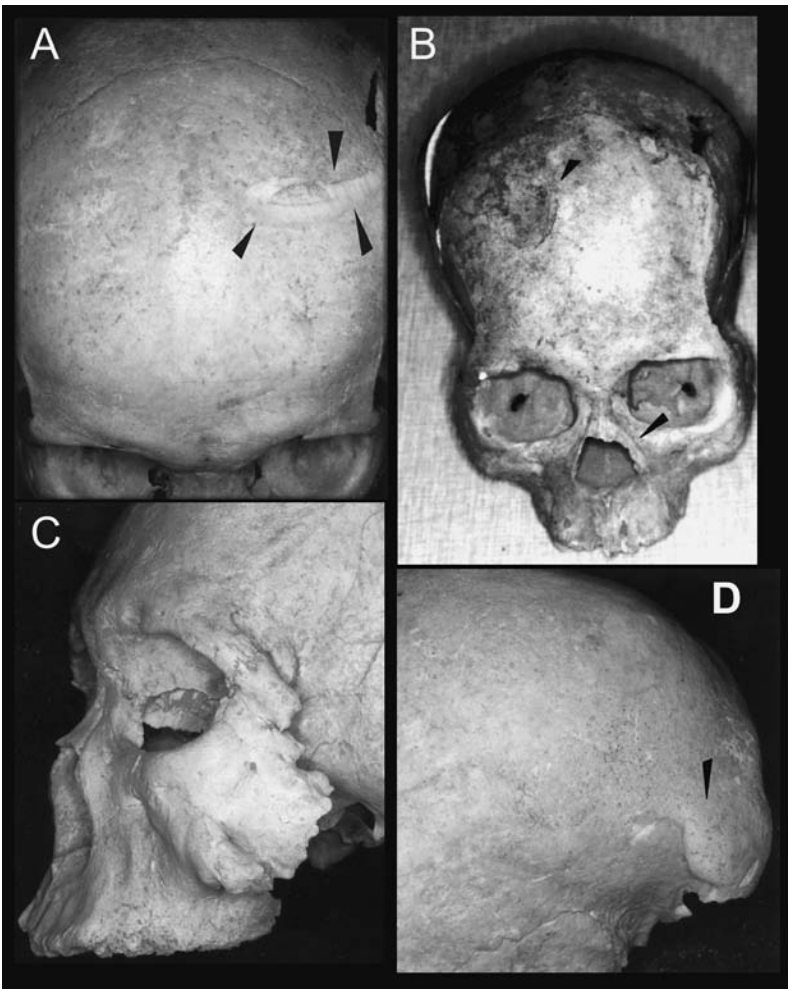

Figure 18.4. Traumatic injuries on Yangshao crania from China. *A,* cut marks on a skull from the Beiliu site (M18); *B,* perimortem depression fracture and a healed fracture of the nasal bones of a skull from Jiangzhai; *C,* healed direct compression fracture of the left zygomatic of a male skull from Jiangzhai (M112:13); *D,* a healed infraction, surrounded by excessive porosity in a skeleton from Shijia (M27:29).

the arm while falling. A female from Shijia (M28:31) had a fracture of the left femur at midshaft. This injury showed evidence of healing, yet no union took place between the two parts of the diaphyses. Substantial bone loss occurred, as the cortical material was only 2–3 millimeters thick, indicating that the limb had gone unused for a period of time before death. Healed fractures were likewise found on two humeri and two clavicles belonging to other Yangshao individuals.

Cranial traumas were less common in the Middle Yangshao collections than in those from Early Yangshao. Only one of the twenty-one Guanjia skulls had a possible perimortem injury. Postcranial fractures were found on the remains of two individuals from the same site: one of the humerus midshaft (M2) and the other of the femoral diaphysis (M13). Both were dislocated, but well healed and remodeled, suggesting that each of the affected individuals survived for an extended period of time after being injured.

Although no skulls from Xipo show evidence of traumatic injury, two individuals had fractures of the ribs and four of eighteen had healed fractures of the ulna. One individual (M4) had fractured both the left and the right ulna, while another (M2) had fractured and dislocated both radius and ulna at midshaft. These postcranial fractures affected male skeletons exclusively.

No cranial fractures were detected on the remains of any Longshan individual examined; small sample sizes and/or sampling error may skew our interpretation toward an apparent lack of interpersonal violence for this period.

Summary

The human skeletal collections examined for the study reported here were recovered from sites in a geographic area encompassing approximately one thousand square kilometers and ranging in time from about 9000 to 2000 BP.

Interpretation of health status for the Peiligang community at Jiahu is complicated by the fragmentary condition of the surviving human remains. Estimated average adult stature for these individuals was the greatest of all among the sample series considered. However, physiological stress, as indexed by high frequencies of porotic hyperostosis and cribra orbitalia, was greater at Jiahu than at the Early Yangshao sites of Jiangzhai and Shijia, although about the same as was evident for the Middle Yangshao collections from western Henan. The limited number of available maxillar and mandibular fragments from Jiahu suggest poor oral health, typical of people reliant on a carbohydrate-rich diet.

Overall, the lowest frequencies of anemia indicators, carious lesions, and tooth loss were found in the Early Yangshao collections. In comparison with individuals from Jiangzhai and Shijia, Middle Yangshao specimens evidenced poor oral health and a higher frequency of physiological stress markers. It is not clear whether these differences reflect a temporal change in subsistence and pathogenic loads, were related to environmental differences and subsistence variation, or are the result of some combination of the above factors. Faunal assemblages at Early Yangshao sites in Shaanxi suggest heavy reliance on wild animals for food (Yuan and Flad 2002). Conversely, domestic pig bones constituted 80–85 percent of the Middle Yangshao Xipo faunal assemblage (Ma 2003).

On the basis of the results of this study, we suggest that there was an overall deterioration in community health after about five thousand years ago for many northern Chinese populations. Frequencies of porotic hyperostosis and cribra orbitalia were especially high at the Longshan site of Meishan, where average adult stature was less than at the Yangshao sites. A possible tubercular spine among this collection might be evidence for the introduction of a new pathogen into the area, although it could more simply reflect lower individual resistance related to physiological stress. The Longshan population at Mengzhuang does not seem to have been affected by dietary deficiencies to the same degree as the Longshan population at contemporaneous Meishan. However, human skeletons from Mengzhuang exhibit frequencies of stress markers comparable to those for the Yangshao individuals from Xipo and Guanjia.

Acknowledgments

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19

Prehistoric Dietary Transitions in Tropical Southeast Asia

Stable Isotope and Dental Caries Evidence from Two Sites in Malaysia

JOHN KRIGBAUM

In low-latitude regions of tropical Southeast Asia, the adoption/development of agriculture does not appear to be as revolutionary an event as in other parts of Asia (Higham 1995; Lu 1999). Although the so-called Neolithic period in Southeast Asia is defined partly by the presence of agricultural foods such as rice (Spriggs 1989, 1996; Glover and Higham 1996; Bellwood 1997), evidence for such domesticates is atypical in Neolithic contexts. To what extent domesticates, native or introduced, played a role in the subsistence of prehistoric foragers in lowland tropical rain forest is unclear (see, for example, Glover 1977; Bellwood 1990; Sather 1995). Nor is it clear how health status changed in these populations from pre-Neolithic to Neolithic times. Recovered human remains from these contexts tend to be poorly preserved, thus limiting systematic paleopathological study. Data are presented here from stable carbon isotopes from human tooth enamel and acquired dental pathology (caries, abscesses, antemortem tooth loss), using skeletal collections from two sites in present-day Malaysia: Niah Cave in northern Borneo (Sarawak) and Gua Cha on the Malay Peninsula. Fragmentary remains from these two sites offer fresh perspectives on prehistoric human subsistence and ecology in the lowland tropics during this transition.

Dense tropical rain forest tends to support low-density populations, and this appears to be the case for early human populations in Southeast Asia (Bellwood 1990). By mid to late Holocene times (after circa 4000 BP), increases in population in the region are inferred from increased numbers of archaeological sites, mainly in caves and rock shelters (Bellwood 1997; Anderson 1997). But it is debated whether human habitation of rain forest habitats was even possible prior to the origins of agriculture. Bailey and colleagues (1989), noting the worldwide paucity of preagricultural sites in rain forest habitats, presented a challenge to anthropologists. They suggested that hunter-gatherer occupa-

tion of rain forests was a relatively recent, Neolithic phenomenon; rain forest foragers could not live year-round in such resource-poor habitats without the support of neighboring agriculturalists supplying requisite carbohydrates (Hutterer 1983; Headland 1987; Headland and Reid 1989). Without contact and trade, hunter-gatherers could not have survived in the rain forest without exploiting other ecological zones (for example, coastal, estuarine, seasonal forest). Bailey and colleagues' hypothesis promotes a heightened awareness of the complexities rain forest habitats pose to questions of prehistoric human subsistence and settlement. The debate underscores the likelihood of mobility by hunter-gatherers in humid lowland rain forest, accessing a variety of habitats and subsisting on a broad spectrum of food resources. Ethnographic literature and hunter-gatherer biology suggest that low-density, mobile, eclectic foraging populations are generally free of many stress-related illnesses and disease that are characteristic of more sedentary communities, which are dependent on agricultural food crops (Cohen 1989).

Recent evidence from a variety of archaeological contexts have addressed these issues (for example, Krigbaum 2001, Kealhofer 2003; Mercador 2003), however, population-based paleopathological assessments based on skeletal remains from tropical Southeast Asia are untenable due to poor preservation. In addition to preservation bias, excavations conducted prior to the 1970s rarely retained or curated entire skeletons.

Teeth help to measure prehistoric lifeways and evaluate the health status of prehistoric foragers and potential farmers in the region (for example, Hillson 1996; Larsen 1997, 2002). In this chapter, dental remains from Niah Cave and Gua Cha in Malaysia are used to measure transitions in subsistence economy and to test the hypothesis of Bailey and colleagues (1989). Each site has both pre-Neolithic and Neolithic components in broadly similar climatic regimes (humid rain forest), permitting differences in time and economy to be assessed. Stable carbon isotope ratios and acquired dental pathology frequencies (caries, antemortem tooth loss, pulp exposure/abscesses) are presented here as evidence to assess change in paleodiet.

Prehistoric Sites and Background

Postglacial climatic changes had a significant impact on tropical ecology and the prehistoric populations of Southeast Asia. During the Last Glacial Maximum (circa 21,000–18,000 BP), lower sea levels linked Borneo, Java, and Sumatra with the Southeast Asian mainland forming Sundaland (Bellwood 1990). Improving climate allowed equatorial rain forest to spread to its present-day extent by the Holocene. Concomitant rise in sea level led to island formation and effectively doubled the available coastline, substantially chang-

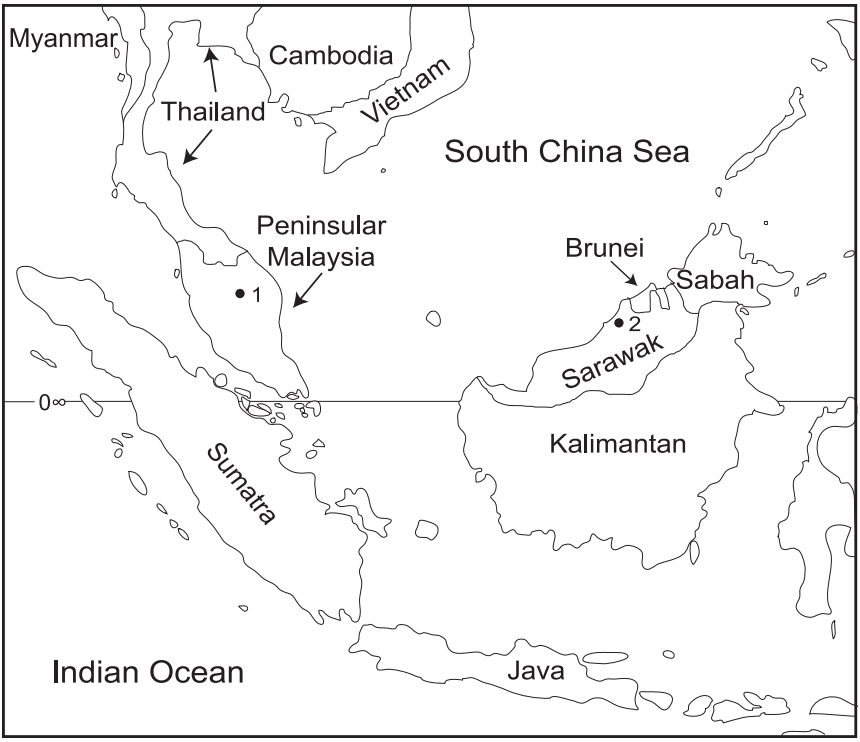

Figure 19.1. Map of tropical Southeast Asia showing major countries/islands and the location of Malaysian archaeological sites featured in this study: (1) Gua Cha and (2) Niah Cave.

ing the landscape. Ecological and cultural changes later in the Holocene influenced the distribution and availability of food, which directly affected human foraging behavior.

Although a great distance apart, Niah Cave and Gua Cha are both situated in primary lowland rain forest and limestone karst (Figure 19.1). Excavations began at both sites in the mid-1950s (for example, Sieveking 1954; Harrisson 1957). Both sites are broadly contemporary (although Niah Cave extends farther back in time), and both sites became the "type sites" for their respective regions. Each, however, is quite culturally distinct.

The Hoabinhian is a regional cultural complex characterized at many late Pleistocene and early–mid Holocene sites in mainland Southeast Asia and Sumatra. It is characterized by edge-ground (unifacial and bifacial) pebble tools and flakes and, when preserved, flexed burials (Gorman 1971; Glover 1977); it is not found in island Southeast Asia (Bellwood 1997). There are Hoabinhian sites throughout the Malay Peninsula, best represented by Gua Cha. Faunal re-

mains present at inland Hoabinhian sites suggest broad spectrum subsistence in lowland rain forest. Indeed, Bailey and colleagues (1989) list Gua Cha and other interior Hoabinhian sites on the Malay Peninsula as evidence countering their hypothesis that rain forests were not uninhabited by preagricultural groups.

On Borneo and neighboring Palawan, sites such as Niah Cave, Madai (Sabah), and Tabon Cave show a flake and edge-ground stone tool tradition distinct from that of mainland Southeast Asia (Bellwood 1997). Terminal Pleistocene flexed burials also are found with faunal remains that reflect more seasonal conditions during the Last Glacial Maximum (Cranbrook 2000; Barker et al. 2002). Low-density, broad-spectrum foragers likely characterize the populations inhabiting these islands and their diverse ecozones.

NIAH CAVE

Niah Cave (Sarawak, East Malaysia) is one of the largest (circa 10.5 hectares, 26.5 acres) caves in Borneo. It is situated near the South China Sea, amid limestone karst formations and lowland swamp and dipterocarp rain forest. Myriad passageways form the bulk of the cave system with multiple openings, the largest being the West Mouth. This entrance contains the longest stratified record of human occupation in island Southeast Asia (Bellwood 1997). Major excavations were conducted in the 1950s and 1960s (Harrisson 1957, 1959, 1972) in the 1970s (Zuraina 1982), and most recently by the Niah Cave Project (Barker et al. 2002, 2007).

Today Niah Cave occupies lowland swamp rain forest, although late Pleistocene climate probably was significantly cooler and probably drier (Barker et al. 2002, 2007). During the Last Glacial Maximum (21,000–18,000 BP), Niah Cave is estimated to have been approximately two hundred kilometers from the coast. Bearded pig and various primates dominate the faunal assemblage, but freshwater shellfish also occur throughout the deposits (Zuraina 1982).

Both pre-Neolithic and Neolithic burial contexts occur, and the West Mouth appears to have been occupied often from the late Pleistocene to the earliest Holocene (Krigbaum 2001, 2005). Later occupation was less regular, its primary function shifting from habitation to mortuary ritual and respite (Krigbaum 2001; Bellwood 1997). A detailed burial classification outlines a variety of burial modes observed during excavation (Harrisson 1967).

Pre-Neolithic burials, without ceramics, include primary flexed and so-called seated burials and secondary "mutilation" burials. This latter category includes the famous late Pleistocene Deep Skull, which likely dates to circa 36,000 BP (Harrisson 1967; Barker et al. 2002, 2007). All other pre-Neolithic human remains are undated but likely terminal Pleistocene in age (21,000–8000 BP) based on analysis of radiocarbon dates from the site and burial con-

text (Krigbaum 2001, 2005). Ceramic-associated remains are mostly primary extended burials, with a few secondary, "burnt" burials, often in earthenware jars, or cremations. These are mid to late Holocene in age, and postdate 4000 BP (Krigbaum 2001, 2005).

It is difficult to identify substantial changes in social system based solely on the archaeological record at Niah Cave; however, the West Mouth was clearly used as a formal mortuary space in the Neolithic which suggests increased sedentism for some groups. It is likely early farmers integrated with foraging groups and shared their respective resources; further work, however, is required to identify these nuances based on the existing information (Sather 1995).

GUA CHA

The rock shelter of Gua Cha (Ulu Kelantan, western Malaysia) is in the middle of the Malay Peninsula in perhumid rain forest with tower karst formations. Pig, deer species, and a variety of monkeys dominate the faunal assemblage. Freshwater shellfish remains (but no marine resources) occur at the site. Hoabinhian occupation of the site was fairly regular, but the site was used almost exclusively as a cemetery during the Neolithic period (Bellwood 1997). Excavations were conducted in 1954 (Sieveking 1954) and in 1979 (Adi 1985). The site contains alluvial deposits that comprise a thick Hoabinhian layer (circa 10,000–3000 BP) and a shallow Neolithic layer (circa 3000–1000 BP). Preserved human skeletal remains are typically flexed, with few grave goods. Neolithic skeletal remains are usually extended and associated with a variety of grave goods including distinctive ceramics. In character and associated material culture, Gua Cha shows a clear cultural connection to the Ban Kao culture from southern Thailand (Bellwood 1993, 1997). Here, too, increased sedentism with dependence on forest resources may be inferred; however, the archaeological evidence for socio-political evidence unfortunately is lacking for many tropical Southeast Asian sites.

Acquired Dental Pathology

Poorly preserved and fragmentary human remains make it difficult to address issues of health comprehensively and systematically. First impressions suggest relatively little skeletal pathology with no visible trend. Bulbeck (2005) reports relatively frequent enamel hypoplasia with no clear trend in time at Gua Cha. He also reports stature declining with time. Acquired dental conditions (for example, dental caries, abscesses, and antemortem tooth loss), however, are useful indicators of paleodiet because dental remains are commonly preserved even when other parts of the skeleton are not.

Table 19.1. Dental Caries Prevalence by Site

	Maxilla			Mandible			
Tooth Class	Teeth Obs.	*N*[a]	%	Teeth Obs.	*N*[a]	%	Total %
Niah Cave (Pre-Neolithic & Neolithic, N=71)							
Incisor	66	7	10.61	36	3	8.33	9.80
Canine	38	0	0.00	22	0	0.00	0.00
Premolar	101	1	0.99	70	2	2.86	1.75
Molar	153	1	0.65	149	4	2.68	1.66
Total	358	9	2.51	277	9	3.25	2.83
Gua Cha (Hoabinhian & Neolithic, N=18)							
Incisor	33	2	6.06	40	2	0.05	5.48
Canine	21	1	4.76	27	1	3.70	4.17
Premolar	45	5	11.11	47	3	6.38	8.69
Molar	63	12	19.05	71	13	18.31	18.66
Total	162	20	12.35	185	19	10.27	11.24

[a] *N* = number of teeth exhibiting dental caries.

Dental caries has received considerable attention as a proxy for diet and health status (Turner 1979; Larsen 1982; Hillson 1996); most studies suggest that starchy carbohydrates associated with the development and adoption of agriculture correlate with significant increases in dental caries.

For this study, carious lesions were recorded by surface only if they penetrated the surface enamel (Hillson 2001). Caries frequency was determined by the tooth count method: individual teeth with observable crowns were totaled against the number of observed teeth affected by carious lesions. Antemortem tooth loss frequency was determined from total loci observed against the number of observed loci with alveolar closure.

This study uses 18 adult dentitions from the 1954 Gua Cha skeletal sample (*N*=25). In total, 347 teeth and 412 loci were scored for acquired dental conditions following standard procedures (Hillson 1996; Buikstra and Ubelaker 1994). Bulbeck reviewed dental conditions present in the 1979 remains (*N*=4) in his master's thesis (Bulbeck 1981; Adi 1985: 96–97) and more recently for the entire Gua Cha burial series (Bulbeck 2005). The Niah Cave skeletal series is more fragmentary but provided 71 adult individuals, with a total of 635 teeth and 736 loci.

Dental caries frequencies show marked differences between the two sites. Tables 19.1 and 19.2 document dental caries prevalence and antemortem tooth loss for the pooled pre-Neolithic and Neolithic samples. Tables 19.3 and 19.4 present dental caries and antemortem tooth loss data for pre-Neolithic- and Hoabinhian-associated remains, while Tables 19.5 and 19.6 present dental caries and antemortem tooth loss data for Neolithic-associated remains from each site. Most striking from these data is the high caries frequency for the pooled Gua Cha sample (11.24 percent) compared to that for Niah Cave

Table 19.2. Total Antemortem Tooth Loss by Site

	Maxilla			Mandible			
Tooth Class	Loci Obs.	*N*[a]	%	Loci Obs.	*N*[a]	%	Total %
Niah Cave (Pre-Neolithic & Neolithic, N=71)							
Incisor	81	9	11.11	87	12	13.79	12.50
Canine	44	2	4.55	42	3	7.14	5.81
Premolar	100	2	2.00	100	9	9.00	5.50
Molar	122	5	4.09	160	25	15.63	10.64
Total	347	18	5.19	277	49	17.69	9.10
Gua Cha (Hoabinhian & Neolithic, N=18)							
Incisor	40	5	12.50	56	3	5.36	8.33
Canine	22	1	4.55	28	1	3.57	4.00
Premolar	48	2	4.17	60	5	8.33	6.48
Molar	65	5	7.69	93	17	18.28	13.92
Total	175	13	7.43	237	26	10.97	9.47

[a] *N* = number of observed loci exhibiting antemortem tooth loss.

Table 19.3. Pre-Neolithic Dental Caries Prevalence by Site (Tooth Count)

	Maxilla			Mandible			
Tooth Class	Teeth Obs.	*N*[a]	%	Teeth Obs.	*N*[a]	%	Total %
Niah Cave (Pre-Neolithic, N=25)							
Incisor	36	0	0.00	19	0	0.00	0.00
Canine	18	0	0.00	12	0	0.00	0.00
Premolar	49	0	0.00	30	1	3.33	1.27
Molar	72	0	0.00	47	0	0.00	0.00
Total	175	0	0.00	108	1	0.93	0.35
Gua Cha (Hoabinhian, N=9)							
Incisor	22	0	0.00	24	2	8.33	4.35
Canine	12	1	8.33	15	0	0.00	3.70
Premolar	23	3	13.04	22	0	0.00	6.67
Molar	32	3	9.38	40	3	7.50	8.33
Total	89	7	7.87	101	5	4.95	6.32

[a] *N* = number of teeth exhibiting dental caries.

Table 19.4. Pre-Neolithic Antemortem Tooth Loss by Site

	Maxilla			Mandible			
Tooth Class	Loci Obs.	*N*[a]	%	Loci Obs.	*N*[a]	%	Total %
Niah Cave (Pre-Neolithic, N=25)							
Incisor	36	1	2.78	24	0	0.00	1.67
Canine	20	1	5.00	11	0	0.00	3.23
Premolar	43	2	4.65	23	0	0.00	3.03
Molar	55	3	5.45	32	2	6.25	5.75
Total	154	7	4.55	90	2	2.22	3.69
Gua Cha (Hoabinhian, N=9)							
Incisor	27	2	7.41	27	2	7.41	7.41
Canine	14	0	0.00	13	0	0.00	0.00
Premolar	26	2	7.69	30	3	10.00	8.93
Molar	36	3	8.33	51	9	17.65	13.79
Total	103	7	6.79	121	14	11.57	9.38

[a] *N* = number of observed loci exhibiting antemortem tooth loss.

Table 19.5. Neolithic Dental Caries Prevalence by Site (Tooth Count)

	Maxilla			Mandible			
Tooth Class	Teeth Obs.	*N*[a]	%	Teeth Obs.	*N*[a]	%	Total %
Niah Cave (Neolithic, N=46)							
Incisor	30	7	23.33	17	3	17.65	21.28
Canine	20	0	0.00	10	0	0.00	0.00
Premolar	52	1	1.92	40	1	2.50	2.17
Molar	81	1	1.23	102	4	3.92	2.73
Total	183	9	4.92	169	8	4.73	4.83
Gua Cha (Neolithic, N=9)							
Incisor	11	2	18.18	16	0	0.00	7.41
Canine	9	0	0.00	12	1	8.33	4.76
Premolar	22	2	9.09	25	3	12.00	10.64
Molar	31	9	29.03	31	10	32.26	30.65
Total	73	13	17.81	84	5	5.95	17.19

[a] *N* = number of teeth exhibiting dental caries.

Table 19.6. Neolithic Antemortem Tooth Loss by Site

	Maxilla			Mandible			
Tooth Class	Loci Obs.	*N*[a]	%	Loci Obs.	*N*[a]	%	Total %
Niah Cave (Neolithic, N=46)							
Incisor	81	9	11.11	87	12	13.79	12.50
Canine	44	2	4.55	42	3	7.14	5.81
Premolar	100	2	2.00	100	9	9.00	5.50
Molar	122	5	4.09	160	25	15.63	10.64
Total	347	18	5.19	277	49	17.69	9.10
Gua Cha (Neolithic, N=9)							
Incisor	40	5	12.50	56	3	5.36	8.33
Canine	22	1	4.55	28	1	3.57	4.00
Premolar	48	2	4.17	60	5	8.33	6.48
Molar	65	5	7.69	93	17	18.28	13.92
Total	175	13	7.43	237	26	10.97	9.47

[a] *N* = number of observed loci exhibiting antemortem tooth loss.

(2.83 percent). By period, caries frequency is even more telling in that pre-Neolithic frequencies at Gua Cha remain fairly high (6.32 percent) compared to a single carious lesion recorded in the pre-Neolithic Niah Cave sample (0.35 percent). Neolithic frequencies are higher at Niah Cave (4.83 percent) and very high at contemporary Gua Cha (17.19 percent). Data on location of carious lesions are presented in Table 19.7, and there is a distinct difference between Niah Cave and Gua Cha. Gua Cha individuals are more likely to be affected by gross dental caries on their molars (presumably initiated as pit and fissure or occlusal caries), whereas Niah Cave individuals show interproximal caries on their incisors. Although wear data are not presented here (but see Bulbeck 1981, 2005), Neolithic wear is less extreme than pre-Neolithic wear at both sites.

Table 19.7. Total Number of Pulp Exposures, Abscesses, and Dental Caries by Site and Context

			Caries by Location					
	Abscesses	Pulp Exposure	Gross	Occlusal	Interproximal	Cervical	Smooth	Total
Niah Cave (N=12)								
Pre-Neolithic (N=3)	4	0	0	0	1	0	0	1
Neolithic (N=9)	0	0	3	3	10	1	0	17
Total	4	0	3	3	11	1	0	18
Gua Cha (N=14)								
Hoabinhian (N=7)	12	3	2	2	2	6	0	12
Neolithic (N=7)	3	0	10	3	7	7	0	27
Total	15	3	12	5	9	13	0	39

There is surprising similarity in antemortem tooth loss (AMTL) between Niah Cave (9.10 percent) and Gua Cha (9.47 percent). The pre-Neolithic Niah Cave sample has a low prevalence (3.69 percent) compared to Hoabinhian Gua Cha (9.38 percent); by contrast, the Neolithic Niah Cave prevalence is quite similar (9.10 percent) to the Neolithic Gua Cha remains (9.47 percent) albeit differing in loci affected. These data suggest that individuals at each site probably lost their teeth for different reasons. The high caries frequency at Gua Cha would explain the frequency of antemortem tooth loss in addition to the extreme wear observed for that site. Bulbeck (2005) notes greater rates of wear for Hoabinhian individuals than for Neolithic individuals at the site. There are examples of cariogenic foods that cause rapid wear, and yams and various tuber species certainly would be included among such foods (Bulbeck 1981; Kuchikura 1993).

Stable Isotope Analysis

Most paleodietary studies use data derived from bone collagen. Issues of diagenesis, however, create problems for skeletal remains from humid, low-latitude contexts. To date, bone collagen has not been recovered from Gua Cha or Niah Cave remains. Tooth enamel, which resists diagenesis, is used here to identify trends in prehistoric subsistence at these two sites.

Third-molar tooth enamel from pre-Neolithic (N=19) and Neolithic (ceramic-associated) burials (N=32) was sampled to provide "adult" dietary signals. Teeth were photographed, cast, and cleaned prior to the removal of enamel for analysis, following procedures outlined in Krueger and Sullivan 1984, Lee-Thorp and van der Merwe 1991, Ambrose and Norr 1993, Koch et al. 1994, and Cerling and Harris 1999.

Krigbaum (2001, 2003) outlines a model for stable carbon isotopes in a tropical rain forest habitat. The model demonstrates how carbon is assimilated

Table 19.8. Descriptive Statistics for Human $\delta^{13}C_{PDB}$ and $\delta^{18}O_{SMOW}$ Results for Tooth Enamel by Site and Time Period

	Pre-Neolithic/Hoabinhian		**Neolithic**	
	Niah Cave	Gua Cha	Niah Cave	Gua Cha
$\delta^{13}C$				
N	15	4	28	4
Mean	-14.4‰	-15.3‰	-13.2‰	-13.1‰
Std. Dev.	0.85	0.29	0.84	0.69
Range	-15.7 to -12.2‰	-15.6 to -15.0‰	-14.8 to -11.3‰	-14.2 to -12.6‰
$\delta^{18}O$				
N	15	4	28	4
Mean	24.2‰	24.4‰	23.8‰	25.3‰
Std. Dev.	1.11	0.36	0.58	0.82
Range	21.9 to 26.2‰	24.0 to 24.8‰	22.5 to 24.8‰	24.3 to 26.2‰

Note: Results calculated as incidence per mil (‰).

into the food web by means of photosynthesis and its potential effect on the $\delta^{13}C$ measured in various tissues of the flora and fauna. Particularly important in the current analysis is the variability of $\delta^{13}C$ values of C_3 plants in closed canopy vs. open field habitats. In tropical rain forest, a major consideration in interpreting $\delta^{13}C$ values is interpreting this "canopy effect," whereby $\delta^{13}C$ values vary in plants at the canopy compared to ground level (van der Merwe and Medina 1989, 1991; Ambrose 1993; Heaton 1999; Cerling et al. 2004). Lighter biogenic CO_2 results in increasingly negative $\delta^{13}C$ values along the forest floor and this discrimination of ^{13}C for the lighter carbon isotope, ^{12}C, is reflected throughout the food web of the forest, including human tooth enamel.

Collective results of $\delta^{13}C$ and $\delta^{18}O$ are presented in Table 19.8 and Figure 19.2; however, the discussion focuses only on the $\delta^{13}C$ variation, as $\delta^{18}O$ variation (reflecting climate and temperature) falls outside of the scope of this study. The Hoabinhian burials from Gua Cha show surprisingly negative $\delta^{13}C$ values (average, 15.3‰) consistent with expectations of broad-spectrum subsistence under closed-canopy conditions independent of fringe resource zones. These data have important implications with respect to Bailey and colleagues' (1989) hypothesis that primary rain forests were uninhabitable prior to agriculture. The $\delta^{13}C$ values suggest human occupation in closed canopy forest. Niah Cave's pre-Neolithic $\delta^{13}C$ results (average, 14.4‰) show a greater range than the Hoabinhian sample from Gua Cha. Both pre-Neolithic samples, however, have significantly more negative values (Student's *t*-test, .01 level) than do their respective Neolithic samples. The Neolithic $\delta^{13}C$ values are quite similar on average for Niah Cave (-13.3‰) and Gua Cha (-13.2‰).

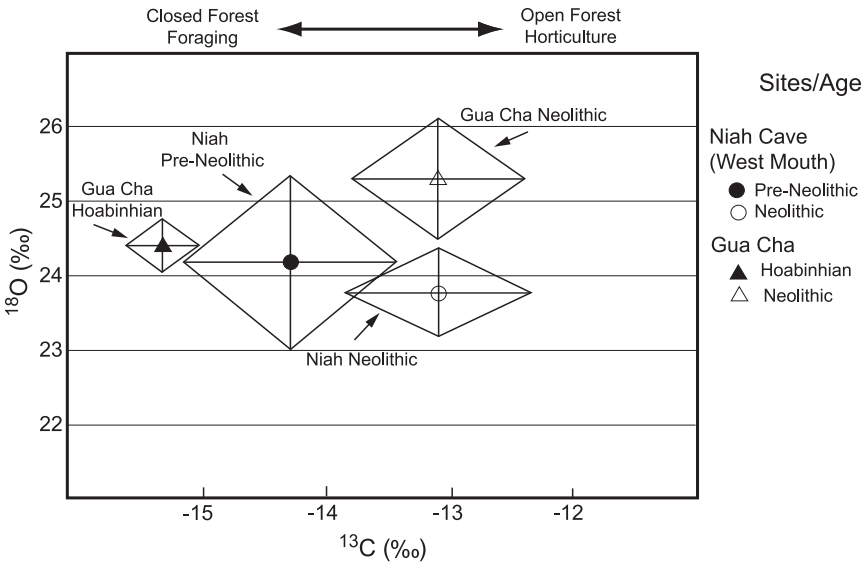

Figure 19.2. Pre-Neolithic and Neolithic mean and standard deviations for $\delta^{13}C_{PDB}$ and $\delta^{18}O_{SMOW}$ values (tooth enamel apatite) for human burials from Malaysia.

Discussion

Tooth enamel $\delta^{13}C$ values suggest a change in subsistence between pre-Neolithic Niah Cave burials at the West Mouth and those Neolithic burials associated with ceramics. Heterogeneity of $\delta^{13}C$ values suggest that some individuals at Niah Cave may have foraged more than others. The earliest ceramics from Borneo date to circa 4200 BP (3850 ^{14}C years BP), based on dates of rice husks from Gua Sireh (Bellwood et al. 1992). These dates are quite early for the spread of rice in the islands of Southeast Asia and certainly are indicative of important Neolithic trends at this time. On the Malay Peninsula, rice has been considered a recent arrival (Hill 1977). However, Bellwood (1993, 1997) argues that, since rice was apparently grown and/or supplied to sites in southern Thailand such as Khok Phanom Di (Higham 1989; Tayles 1999), it likely arrived on the peninsula in combination with other facets of Neolithic Ban Kao–related material culture. The shift toward increasingly positive $\delta^{13}C$ values reflects a trend of individuals/populations collecting and eating plant goods grown in more open habitats.

The dental data presented above complement the isotopic results. Broad-spectrum foraging is based on the local ecological contingencies facing a given

population. The increased frequency of dental caries in pre-Neolithic Hoabinhian individuals is in stark contrast to that observed among the pre-Neolithic Niah Cave individuals. This suggests a markedly different dietary regime prior to the "arrival" of rice in each region. Thus, the different diets would have affected oral health in different ways, but both would be considered as available to broad-spectrum foragers based on the archaeological findings from each site.

The analysis of skeletal materials from Neolithic individuals at both sites seems to reflect consumption of plant foods grown in open plots. To what extent this suggests the presence of rice, a C_3 crop, is unknown, for rice is absent from many archaeological contexts. However, purposeful maintenance of plants grown in open fields was clearly practiced by Neolithic Gua Cha and at least some of the groups represented at Niah Cave (Krigbaum 2003, 2005). Neolithic health status, as inferred from acquired dental pathologies, is more comparable between the two sites, but certainly, local contingencies still varied. More detailed paleopathological study is required to infer the health status of the hunter-gatherers and part-time foragers (open-forest horticultural groups) represented at these two sites. Unfortunately, data on post-Neolithic adaptations in this region are not presently available.

Conclusion

Sites in Southeast Asia may be identified as "Neolithic" by their cultural patterns, but there is little direct evidence for agriculture in lowland tropical archaeological sites. Although human skeletal material from tropical Southeast Asia is fragmentary, stable carbon isotope ratios and acquired dental pathologies help us to reconstruct subsistence regimes for these populations. In tropical Southeast Asia, the transition to agriculture was less distinct than in other parts of the world, including subtropical regions of mainland Southeast Asia (for example, see Tayles et al. 2000; Domett and Tayles, this volume). The broad-spectrum foraging of the pre-Neolithic continued during the Neolithic. However, it would be simplistic to infer that all broad-spectrum diets are the same. Indeed, sites in this region offer important new perspectives with respect to the human forager-farmer continuum (Harris 1989).

Acknowledgments

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20

Population Health from the Bronze to the Iron Age in the Mun River Valley, Northeastern Thailand

KATE DOMETT AND NANCY TAYLES

During the second half of the second millennium BP, a significant statelike civilization arose in Southeast Asia. This included the establishment of the Khmer kingdom, centered on Angkor in Cambodia and including the Mun River valley in northeastern Thailand. Prior to this occurrence, communities were undergoing significant change as they became more centralized politically and able to support increasing population numbers (Higham 2002; O'Reilly 2000). Using two skeletal samples from sites dated between 3400 BP and 1600 BP, in this chapter we examine population health during the period prior to the development of the Angkorian state.

The prehistoric site of Ban Lum Khao (BLK) includes a Bronze Age cemetery in use between approximately 3400 BP and 2500 BP (Higham 2002). Noen U-Loke (NUL), an Iron Age site, is in close proximity (Figure 20.1) and has been dated to circa 2300–2200 BP to 1700–1600 BP (Higham 2002). The two sites are in similar natural environments, both mounded sites on the lower river terraces of the Mun River valley. Boyd and McGrath (2001a), while detailing a landscape that ranges from grasslands to rice cultivation and some forest and woodlands, acknowledge that some site-specific differences may exist, particularly as communities changed the way in which they exploited their environment. We assume that the skeletal samples are relatively homogeneous, genetically, both between and within the samples, although genetic heterogeneity may be possible.

The first use of copper began after 3500 BP in northeastern Thailand. Although no bronzes were recovered from BLK, the trading of ingots and casting implements was evident. Other key characteristics include an increasing reliance on rice agriculture. The surrounding environment was suitable for intensive irrigated wet rice agriculture (Welch 1985). The initial occupation layer (late Neolithic) at BLK also included shellfish, fish, turtles, and mammalian bones such as water buffalo, deer, pig, and domesticated dog (Higham and Thosarat 1998). Except for water buffalo, these species continued into the later Bronze Age layers. Their presence in the occupation layers implies a var-

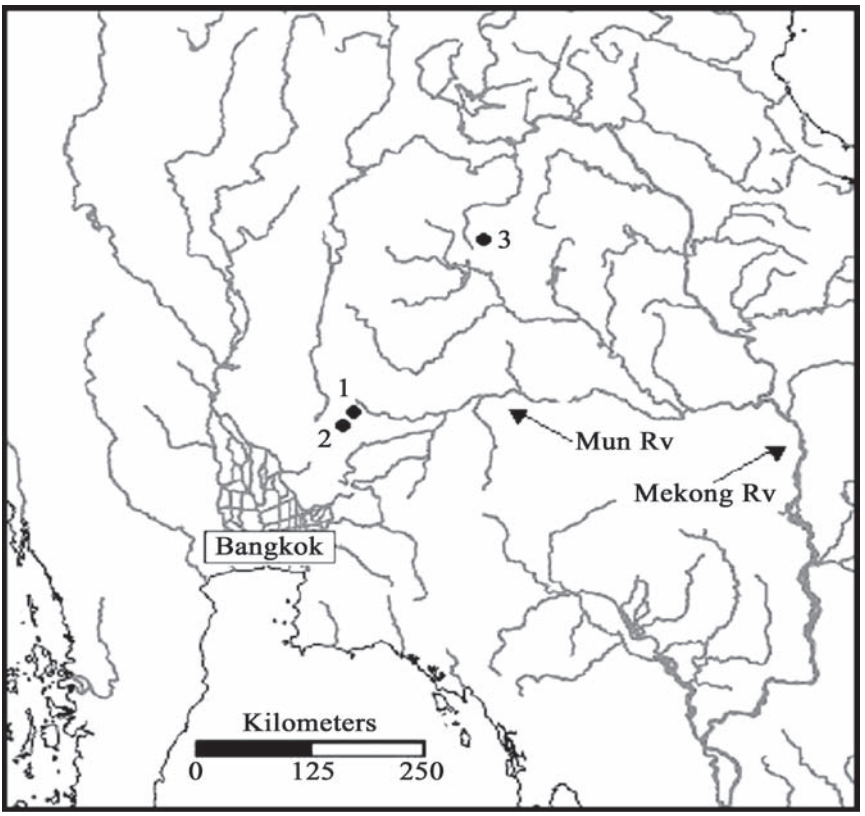

Figure 20.1. Map of northeastern Thailand including (1) Ban Lum Khao, (2) Noen U-Loke, and (3) Ban Chiang.

ied subsistence, combined with rice and other plants that have not been preserved. BLK was most likely an autonomous community (Higham 2002).

In the last half of the third millennium BP, hierarchical and centralized societies were established in the Mun River valley, with widening exchange networks. Iron working assisted in a further intensification of rice agriculture, and rice was an abundant staple at NUL. This abundance is demonstrated compellingly by the use of rice as the backfill of human graves. Other dietary indicators include butchered bones from pig, cattle and water buffalo (McCaw forthcoming), fish (Thosarat 2000), and other plant foods (Boyd and McGrath 2001b).

Materials and Methods

The BLK sample comprises 110 individuals, with generally well-preserved bone tissue, but only 45 percent were complete or nearly complete (Domett 2001).

The NUL sample represents 120 individuals, but the bone tissue is generally poorly preserved and only 33 percent of the skeletons were more or less complete (Tayles and Buckley 2004).

Measures of health include demography, stature, linear enamel hypoplasia (LEH), dental pathologies, trauma, and disease. The methods (previously reported in detail) are briefly described here.

Determining the age at death of subadult material was based on the development of dentition and diaphyseal length modified for Thai populations (Kamalanathan et al. 1960). Epiphyseal fusion was used in children between 12 and 15 years old. A multifactorial approach was taken in estimating the age at death of adults, including late-fusing epiphyses, pubic symphysis morphology, and dental wear. Sex was determined by standard morphological observations.

Stature was estimated using equations derived from modern Thai and Chinese cadavers (Sangvichien et al. n.d., 1985).

Linear enamel hypoplasia was identified macroscopically as transverse lines or grooves across the tooth enamel. Only the presence or absence of one or more defects per tooth was recorded.

Caries were identified macroscopically as necrotic cavities in the tooth crown or root. Every permanent tooth present and visible was assessed. Attrition was graded, using a scale of 1 to 8, for every tooth present (Molnar 1971). Advanced attrition is analogous to a grade 6 to 8 on this scale, indicating pulp exposure. Periapical bony cavities observed in the alveolar bone surrounding each tooth position represent inflammatory or infectious reactions of the periapical tissues or teeth and were recorded for each tooth position where observable. The data are presented both per tooth and per individual. Antemortem tooth loss was also recorded for every tooth position possible, by evidence of remodeling of the alveolar bone surrounding the socket as a positive sign of tooth loss during life.

The comparison of trauma and disease between the two sites is limited by poor preservation of the NUL material, which precludes quantification of these data. However, where possible, prevalence is described. Evidence of disease and trauma is considered an important part of comparing the quality of life between the two samples; therefore, comments and prevalences where possible are presented here.

Results

PALEODEMOGRAPHY

The demographic profiles in Table 20.1 provide information regarding key differences in mortality for age and sex. Overall, the level of subadult mortality is very similar between BLK and NUL, at 46 percent and 44 percent, respectively. These levels are at the upper range for prehistoric Southeast Asian sites (Domett 2001; Doublas 1996) and are suggestive of a good recovery rate for these small skeletons.

Overall, levels of subadult mortality between the samples are similar, but there are some significant differences in the distribution of deaths. A significantly higher proportion of children (as opposed to infants) died at BLK than at NUL: NUL, 12.5 percent; BLK, 27.2 percent (Fisher's Exact Test [FET] *p*-value=0.003). In particular, the BLK sample has a significantly higher proportion of children in the 5–9–year-old category (10 percent) compared with NUL (2.5 percent) (FET *p*-value=0.025). BLK mortality is higher in all other childhood subgroups as well, but not to a statistically significant level.

Adult mortality is similar in all age categories between the samples, with both samples showing few late adolescents dying and the highest proportion of adults dying in the young adult age range and decreasing through to old age.

Table 20.1. Age and Sex Distribution of Ban Lum Khao and Noen U-Loke Samples

Age Category	**Ban Lum Khao**			**Noen U-Loke**			
Subadults	*N* (% of total)			*N* (% of total)			
0–0.9	21 (19.1)			37[a] (30.8)			
1–4	14 (12.7)			9 (7.5)			
5–9	11 (10.0)			3 (2.5)			
10–14	5 (4.5)			3 (2.5)			
? age	0 (0.0)			1 (0.8)			
Subtotal	51 (46.4)			53 (44.2)			
	N (% of adults)			*N* (% of adults)			
Adults	Females	Males	Total	Females	Males	? sex	Total
15–19	2 (1.8)	3 (2.7)	5 (4.5)	0 (0.0)	2 (1.7)	2 (1.7)	4 (3.3)
20–29	17 (15.5)	7 (6.4)	24 (21.8)	8 (6.7)	13 (10.8)	4 (3.3)	25 (20.8)
30–39	7 (6.4)	9 (8.2)	16 (14.5)	7 (5.8)	5 (4.2)	3 (2.5)	15 (12.5)
40–49	4 (3.6)	7 (6.4)	11 (10.0)	6 (5.0)	4 (3.3)	1 (0.8)	11 (9.2)
? age	2 (1.8)	1 (0.9)	3 (2.7)	0 (0.0)	3 (2.5)	9 (7.5)	12 (10.0)
Subtotal	32 (29.1)	27 (24.5)	59 (53.6)	21 (17.5)	27 (22.5)	19 (15.8)	67 (55.8)
Total (adults + subadults)			110 (100)				120 (100)

Note: Ages are given in years. "? age" and "? sex" denote individuals of indeterminate age and sex, respectively.

[a] Includes two late fetal skeletons.

Table 20.2. Adult Stature (cm) Summary Statistics

Site	Mean	*N*	SD	Range	Sexual Dimorphism[a]
Female					
Ban Lum Khao	154.7	25	3.8	147.9–162.2 (14.3)	6.1
Noen U-Loke	154.6	4	4.7	151.5–161.6 (10.1)	8.7
t-test *p*-value	0.97				
Male					
Ban Lum Khao	164.7	18	6.2	152.4–174.9 (22.5)	
Noen U-Loke	169.3	9	3.1	165.3–173.7 (8.4)	
t-test *p*-value	0.049				

Note: *N* = number of individuals; SD = standard deviation.
[a] % of male stature.

However, there is a significantly higher proportion of young adult females in the BLK sample (15.5 percent) compared with the NUL sample (6.7 percent) (FET *p*-value=0.035). Overall, there is a significantly higher proportion of adult females in the BLK sample (29.1 percent) compared with the NUL sample (17.5 percent) (FET *p*-value=0.042). However, in both samples the sex ratio is nearly equal, implying a good representation of both sexes in each sample. The sex ratio of females to males at BLK is 1.2:1 and in the NUL sample is 0.8:1. This is not significantly different (FET *p*-value=0.33).

STATURE

The following comparison of mean stature for each sample should be considered with the caveat of a small sample size from NUL. Only 19 percent of the adult sample from NUL had complete or reconstructible long bones that were measurable. In contrast, stature was estimated for nearly three-quarters (73 percent) of the BLK adult sample.

The mean stature for females is almost identical between the sites, but male mean estimates show significant differences (Table 20.2). The NUL males (169.3 centimeters) are, on average, 4.6 centimeters taller than BLK males (164.7 centimeters) (Student's *t*-test *p*-value=0.049). The BLK males show a wider range of statures, with individuals both taller and shorter compared with the NUL sample. The small sample size from NUL is likely to have influenced the limited range of their statures. Notably, BLK males display a wider range of statures (22.5 centimeters) than do females (14.3 centimeters).

The level of sexual dimorphism in both samples is within the normal range (5–10 percent) (Molnar 1992). The NUL sample had a slightly higher level of sexual dimorphism (8.7 percent) than the BLK sample did (6.1 percent).

LINEAR ENAMEL HYPOPLASIA

Analysis of linear enamel hypoplasia (LEH) must ensure that one sample does not have a significantly higher proportion of canines and incisors compared with the other (that is, that the percentages of anterior teeth are comparable). Both samples for this study had very similar percentages of canines and incisors, both mandibular and maxillary, of between 35 percent and 38 percent. Therefore, we have assumed that the data presented below are not biased in this way.

Subadults

No deciduous teeth in the BLK or NUL samples had LEH. In the permanent teeth of the BLK subadults, 28.3 percent (30/106) of teeth and 26.1 percent (6/23) of individuals had LEH (Table 20.3). In the same sample from NUL, there were slightly fewer individuals with LEH (3/15, 20.0 percent), but significantly fewer teeth were affected (4/57, 7.0 percent) compared with those of the BLK subadults (FET p-value<0.01).

Adults

The level of advanced attrition may affect the observation of LEH. Evidence was found for a significantly higher proportion of advanced attrition in the NUL sample. The proportion of LEH, therefore, does not include teeth with

Table 20.3. Proportion of Teeth with Linear Enamel Hypoplastic Defects

	Ban Lum Khao		**Noen U-Loke**		**Site Difference**
	A/*N*	%	A/*N*	%	χ^2 *p*-value
Subadults[a]					
By tooth	30/106	28.3	4/57	7.0	<0.01
By individual	6/23	26.1	3/15	20.0	0.72
Female					
By tooth	54/429	12.6	39/258	15.1	0.35
By individual	11/24	45.8	12/20	60.0	0.38
Male					
By tooth	35/308	11.4	20/304	6.6	0.04
By individual	6/18	33.3	10/22	45.5	0.53
? sex					
By tooth			13/114	11.4	
By individual			6/10	60.0	
Total					
By tooth	89/737	12.1	72/676	10.7	0.40
By individual	17/42	40.5	28/52	53.8	0.22

Note: The teeth with advanced attrition have been removed from the calculation for adult teeth. A = affected with LEH; *N* = total number of teeth or individuals observed; ? sex = indeterminate sex.

[a] Permanent teeth only.

advanced attrition. Overall, BLK and NUL show very similar levels of LEH in adults, with 12.1 percent and 10.7 percent of teeth affected, respectively (χ^2 p-value=0.40) (Table 20.3). The number of individuals affected is slightly lower in the BLK sample (40.5 percent compared with 53.8 percent in NUL), but this difference is not significant (χ^2 p-value=0.22).

There are no significant differences in the proportion of teeth or individuals affected with LEH in the female samples. BLK females show slightly fewer LEH (12.6 percent of teeth, 45.8 percent of individuals) than do the NUL females (15.1 percent of teeth, 60.0 percent of individuals).

BLK males exhibit almost twice the proportion of teeth with LEH (11.4 percent) compared with NUL males (6.6 percent) (χ^2 p-value=0.04). The individual count data do not show the same large difference, and in fact, the NUL males more commonly have LEH (45.5 percent) than BLK males do (33.3 percent), but the difference is not statistically significant (χ^2 p-value=0.53).

TRAUMA

Fracture rates for the major long bones in the BLK sample are presented for comparison with other studies (Domett and Tayles 2006) (Table 20.4). No fractures were observed in the NUL sample.

The BLK sample showed a predominance of forearm fractures, particularly in males. Five of seven fractured radii and ulnae were from males. Other bones fractured included those of the feet, the mandible, and one nasal fracture in a male individual also presenting with a healed ulnar fracture.

Other signs of trauma were evident in the vertebrae of both BLK and NUL adults. Spondylolysis was present in eight individuals (three females, five males) in the BLK sample; no fracture was found in the NUL sample. Vertebral compression or wedge fractures were found in four individuals from BLK and one from NUL.

Table 20.4. Fracture Rates of the Major Long Bones of Adults in the Ban Lum Khao Sample

	Ban Lum Khao	
Bone	A/*N*	%
Clavicle	1/39	2.6
Humerus	0/37	0
Radius	3/48	6.3
Ulna	4/40	10.0
Femur	0/37	0
Tibia	0/34	0
Fibula	1/29	3.4
Total	9/264	3.4

Note: A = number of bones affected; *N* = number of complete adult bones observed.

In the BLK sample, there were four wrist and ankle injuries, including one with ankylosis of the central tarso-metatarsal joints in the foot that was likely the result of an accident. The NUL sample showed evidence of a foot injury in one adult. A further indication of trauma at this site was the in situ discovery of a spearhead in the spine of an adult male.

JOINT DISEASE

Fragile epiphyseal ends of bones commonly were not preserved in the NUL material, preventing any quantifiable and sensible estimate of joint disease in this material. The joint disease in the BLK sample is described in Domett (2001) and is summarized here.

The prevalence of osteoarthritis was analyzed in all the major appendicular joints in the BLK sample. The percentage of individuals with one or more joints affected by osteoarthritis is 33.3 percent (15.4 percent of females, 54.5 percent of males). The joints most commonly affected were the elbows (6/22, 27.3 percent), shoulders (4/18, 22.2 percent) and feet (6/31, 19.4 percent). Males were more commonly affected in all joints compared with females.

Osteophytosis in the intervertebral body joints was recorded in 31.7 percent of the adult sample of BLK, most frequently in the lumbar region. Again males were more frequently affected than females. Three individuals from BLK displayed Schmorl's nodes. In the NUL sample, four adults with observable vertebrae showed no osteophytosis or Schmorl's nodes.

INFECTIOUS DISEASE

There is little evidence of localized infectious disease in either sample. Individuals at BLK suffered from ear infections (a young and an old female), localized tibial periostitis (a 2-year-old), and localized osteomyelitis in the right radius (a young female).

Only one case of localized infection was observed in the NUL material: tibial periostitis in a middle-aged adult. However, there was more evidence of systemic infections, possibly including leprosy and tuberculosis (Tayles and Buckley 2004).

At BLK, one 6–month-old infant had periostitis in both tibiae and cribra orbitalia; one middle-aged female had possible osteomyelitis in both ulnae. Lesions in the thoracic and lumbar vertebrae of a young woman may be severe disc degeneration, osteomyelitis, or brucellosis but are most consistent with the latter.

Excluding neonates, we found a prevalence of systemic infectious disease of 3.4 percent (3/89) for BLK and 7.7 percent (3/39) for NUL (FET p-value=0.368).

OTHER PATHOLOGY

Cribra orbitalia (CO) was evident in two of eleven observable subadults from the BLK sample (27.3 percent) (Halcrow, pers. comm.). No cribra orbitalia was observed in adults.

Two children from BLK displayed possible metabolic disorders, and two adults had noninfectious conditions.

DENTAL HEALTH

The majority of conditions associated with dentition are age related. In the comparison of age structure of the individuals contributing teeth or tooth positions observable for each condition assessed here, significant differences were identified between the samples when males and females were compared separately. However, no significant age-structure difference was apparent when the total samples were compared. Given these findings, to remove the age bias between the sexes, it is appropriate to consider only the total percentages for each condition rather than the percentages divided by sex.

CARIES

The tooth-count data for subadults with caries show low rates (0–2.2 percent) in both samples (Table 20.5). More subadults were affected in the BLK sample (14.8 percent) than in the NUL subadults (7.7 percent); however, the difference is not significant (FET p-value=0.65).

The proportion of adult teeth and individuals affected with carious lesions is also very similar between the samples: 4.5 percent of teeth or 45.2 percent of individuals at BLK compared with 4.8 percent of teeth and 42.6 percent of individuals at NUL (Table 20.6).

ADVANCED ATTRITION

The proportion of teeth affected by advanced attrition was significantly lower at BLK (12.1 percent) than at NUL (15.6 percent) (FET p-value=0.04) (Table 20.6). There were also fewer individuals affected at BLK (33.3 percent) compared with NUL (40.7 percent) but not to a significant level.

This difference in advanced attrition may have affected the observation of other dental conditions. This has been taken into account in the analysis of LEH but could also affect comparative analyses of caries.

TOOTH INFECTION AND INFLAMMATION

The proportion of tooth positions and individuals affected by periapical lesions is significantly lower in the BLK sample (1.3 percent and 14.3 percent, respectively) compared with the NUL sample (6.0 percent and 37.8 percent,

Table 20.5. Proportion of Deciduous and Permanent Teeth with Caries in Ban Lum Khao and Noen U-Loke Subadults

	Ban Lum Khao		**Noen U-Loke**		**Site Difference**
	A/*N*	%	A/*N*	%	FET *p*-value
Deciduous teeth	4/182	2.2	1/89	1.1	>0.99
Permanent teeth	1/92	1.1	0/52	0	>0.99
By individual	4/27	14.8	1/13	7.7	0.65

Note: A = affected; *N* = total number of teeth observed.

Table 20.6. Proportion of Teeth or Tooth Positions Affected by the Listed Dental Conditions in Adults

	Ban Lum Khao		**Noen U-Loke**		**Site Difference**
	A/*N*	%	A/*N*	%	FET *p*-value
Caries					
By tooth	39/874	4.5	46/956	4.8	0.74
By individual	19/42	45.2	23/54	42.6	0.84
Advanced attrition					
By tooth	104/861	12.1	152/977	15.6	0.04
By individual	14/42	33.3	22/54	40.7	0.53
Periapical cavities					
By tooth	15/1138	1.3	34/571	6.0	<0.01
By individual	6/42	14.3	14/37	37.8	0.02
Antemortem tooth loss					
By tooth	59/1138	5.2	69/1334	5.2	>0.99
By individual	13/42	31.0	22/54	40.7	0.39

Note: A = affected; *N* = total number of teeth observed.

respectively) (FET *p*-values of <0.01 and 0.02) (Table 20.6). The comparison may be affected by the small sample size from NUL.

ANTEMORTEM TOOTH LOSS

The proportion of antemortem tooth loss (AMTL) is the same in the tooth-count analysis for both samples (5.2 percent) (Table 20.6). The proportion of individuals affected is somewhat less in the BLK sample (31.0 percent) than in the NUL adults (40.7 percent), but the difference is not significant (FET *p*-value=0.39).

Discussion and Conclusions

Paleodemographic evidence indicates that the BLK sample was characterized by a lower infant mortality but higher childhood mortality, particularly among children 5–9 years old at the time of death (Table 20.1), compared with NUL. The BLK subadults also had significantly higher levels of growth disruption

(as indicated by linear enamel hypoplasia) (Table 20.3). This could imply that many of the children dying prematurely in the BLK community died of chronic problems, as there had been time for stress to affect the dentition. BLK children were perhaps weakened by ill health earlier in life and were fatally affected by acute disease at a later age.

The proportion of infants in the BLK sample was only 19 percent, a lower proportion than expected in a prehistoric population, suggesting underrepresentation. This contrasts with 30 percent at NUL, which is closer to expectations. The difference likely represents sampling error rather than a true change in health status of the population.

A comparison of the adult age structures (Table 20.1) indicates that significantly more young females were dying at BLK. High mortality of children and young adult females may be a response to diminishing food resources (Groube 1996). Low levels of protein in particular can have significant effects on a community, causing a higher child mortality from inefficient lactation and low-quality weaning foods (Groube 1996). Stress at childbirth may also be high. Groube (1996) also suggests that there would be evidence of malnutrition, which could be explained in the poor nonspecific health of the BLK children. However, no archaeological evidence has been found to suggest that there was a shortage of food at BLK.

Evidence of childhood growth and growth disturbance in the adult skeletons indicated that females in the two samples were similarly affected, while males were not. Higher proportions of linear enamel hypoplasia and shorter statures were identified in the BLK males. Assuming a genetic homogeneity between the sites, this could indicate that BLK males who survived to adulthood were more likely to have been affected by childhood illness. In contrast, the NUL males, although showing signs of growth disturbance, grew taller. (Assuming that the small measurable subsample represents the entire NUL population.)

While males at NUL seem to have been more advantaged than the BLK males, the females have similar statures at these two sites. Stini (1985) suggested that males are more affected by stress than females and therefore sexual dimorphism tends to be lower in populations facing difficult conditions. The level of sexual dimorphism in the BLK sample (6.1 percent) is lower than that of NUL (8.7 percent), suggesting more favorable conditions in the latter population.

Overall, the evidence for health during childhood indicates that the community at BLK was experiencing stress that had a deleterious impact on children—particularly on boys, as male adults are shorter in stature, although they do not have significantly more linear enamel hypoplasia than do females. Also of relevance is the wide range of statures within the BLK males (Table 20.3),

suggesting a hierarchical society with inequality in access to food resources, although there is no archaeological evidence of this (O'Reilly 2000). Alternatively, a wider range of statures in males at BLK might reflect the longer time period involved and/or genetic heterogeneity. At NUL, children who survived infancy attained taller adult statures despite growth disturbance prevalences comparable to those found at BLK. This could imply that these children were capable of adequate "catch-up" growth after illness, which in turn suggests that the children's diet at NUL was good enough to allow this to occur.

Evidence for disease between NUL and BLK was not easily comparable, as it was not readily quantifiable for NUL. However, the NUL sample had a slightly higher infection load. Of note are three cases of evidence for systemic infectious disease that raise the question of their source. Long-distance trade with India and China could have brought new diseases (O'Reilly 2000).

The poor condition of the NUL sample complicates any comparison of trauma with BLK. A more hierarchical society in the Iron Age and competition for resources may have culminated in increased interpersonal violence or warfare expressed in an increase in traumatic injuries, but no evidence has been found to support this. Fracture patterns for BLK and some other sites from Thailand are discussed elsewhere in detail (Domett and Tayles 2006).

The two samples had similar levels of caries and antemortem tooth loss, but the NUL sample had significantly higher proportions of advanced attrition and periapical cavities (Table 20.6). The higher prevalence of advanced attrition in the NUL sample suggests a more abrasive diet than at BLK.

The low to moderate caries prevalence in both samples suggests that the diet for these two populations contained only a moderate proportion of cariogenic foods. The increase in the reliance on rice and less emphasis on hunter-gatherer foods would be expected to be one of the key differences between these two samples. However, despite archaeological evidence for increasing rice production, the caries rates are very similar between the two sites. They do not show an increase (Tayles et al. 2000) such as is commonly reported elsewhere during the increasing contribution to diet of other carbohydrate staples. Rice may not be as highly cariogenic as other carbohydrate staples.

Cultural changes in Southeast Asia have resulted in an unusual pattern of health change. Whereas other regions of the world frequently see a decline in health with the transition to agriculture, we conclude that between the two sites studied here there was, in general, an improvement in health.

One difference between Southeast Asia and other regions is the effect of rice as the core of the diet (Juliano 1993). Processing and cooking can greatly alter the nutritional value of all the major cereals. Unpolished, home-pounded rice is the type most likely eaten in prehistoric times; it is associated with the least nutrient loss from processing (Juliano 1993). A comparison of the nutri-

tional value of unprocessed, uncooked whole-grain wheat and maize (corn) from the Americas with raw polished rice grown in Thailand today indicates that despite having the lowest protein levels among cereals, rice has the highest net protein uptake; as a result, the utilizable protein of rice is comparable with that of other cereals (Juliano 1993; USAID 1999a, 1999b). Rice is very low in fat (unless fried), calcium, and iron, and it has low levels of A, B, C, and D vitamins (Puwastien et al. 1999). Of the amino acids, lysine is limiting; however, fish, the most common source of animal protein in the Asian "rice diet," is a good source of lysine (Geiger and Borgstrom 1962). Even with an increasing reliance on rice agriculture, Bronze and Iron Age communities were also continuing their hunting and gathering subsistence practices, ensuring a balanced diet. Although there is no archaeological evidence to suggest that the diet at BLK was deficient compared with that at NUL, the increasing availability of rice at NUL could have improved the nutrition of children.

In addition, the cultivation of wet rice indicates the physical environment of the communities. Rice is the only major cereal with varieties grown in water. The prehistoric settlements in the Mun River valley are surrounded by marshy or swampy habitats, as the sites are frequently situated in low-lying areas of the Mun River floodplain (Higham 2002). The presence of standing water can provide an appropriate breeding habitat for the mosquito vectors of malaria and can be associated with schistosomiasis and Japanese encephalitis. In addition, raw fish, a delicacy eaten in the northeast of Thailand today, can carry liver flukes (Haswell-Elkins and Elkins 1996; Sornmani et al. 1984). Nevertheless, the aquatic environment provides a habitat for fish and other potential sources of food such as snails and frogs that can add to the protein value of the diet.

Environmental changes resulting from human settlement—with changing hydrology, management of arboreal resources, land clearance, and increased standing water—may also have influenced the marked differentiation between Bronze and Iron Age periods in northeastern Thailand (Boyd and McGrath 2001a; White et al. 2003).

The diagnosis of leprosy and tuberculosis in the NUL sample is possibly related to the increasing contact with India and China. The increasing population size and density enabled these infections to be maintained (Tayles and Buckley 2004). However, despite these significant cultural and environmental changes, the NUL population appears relatively healthy in comparison with the BLK community. The diet of NUL people may have improved nutritionally or in its general availability so that survival of children and adults with disease or postinfection was possible.

Overall, despite increasing rates and varieties of infection, we see an apparent general improvement in health, not a decline, between Bronze Age Ban

Lum Khao (before 2500 BP) and Iron Age Noen U-Loke (2300 BP to 1600 BP).

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21

Biological Consequences of Sedentism

Agricultural Intensification in Northeastern Thailand

MICHELE TOOMAY DOUGLAS AND MICHAEL PIETRUSEWSKY

Archaeological skeletal series from northeastern Thailand permit us to examine the biological consequences of the intensification of agriculture on human health in tropical Southeast Asia. Expanding archaeological investigations—such as surveys, site excavations, environmental reconstructions, isotope analyses, and human skeletal analyses—are providing new data on the heterogeneous patterns of the transition to agriculture in this region. Even contemporaneous and proximate communities in Thailand exhibit localized adaptations, including major differences in material, technology, and economics (White 1995). Still, there is a regional trend in subsistence economy through time, from hunting/gathering/cultivation toward rice agriculture (probably with other crops such as millet, beans, and so forth).

Archaeological evidence and paleoenvironmental data in Thailand (for example, Kealhofer 1996, 2002; White et al. 2004) display regional and temporal variability in environmental change. In northeastern Thailand, during the late Pleistocene/early Holocene, there was an increase in forest and subtle changes in the faunal spectrum. During the middle Holocene, the evidence suggests a drier climate, possibly reflecting human impact through major forest disturbances and burning. No human skeletal remains are available from these earlier periods, although artifactual evidence suggests that a lithic-based, hunter/gatherer/cultivator culture existed elsewhere in Thailand and Southeast Asia, even if it has not yet been clearly defined in northeastern Thailand (Gorman 1971; White et al. 2004: 128–29).

Around 4000 BP, evidence for a decline in burning coincides with the appearance of rice and bronze artifacts in archaeological contexts (White et al. 2004: 129). In the northeast, marked forest regeneration occurred around 2900 BP, roughly coincident with the appearance of water buffalo and iron, suggesting intensified wet rice agriculture.

The Sites

Human skeletal remains from two sites, Non Nok Tha and Ban Chiang, are perfectly placed to permit study of the ongoing effects of this transition to agriculture and its intensification in northeastern Thailand (Figure 21.1).

The mound site of Non Nok Tha (circa 5000/4500–2500 BP) has produced a total of 180 burials, some with evidence of domestic pigs and cattle. The site is located in the Phu Wiang region of the western plateau, near the mountains and at the junction of two streams along a tributary of the Chi River. Three landforms were readily exploitable by the inhabitants: mountains for hunting and gathering; lowlands for possible dry-field cultivation and other foraging opportunities; and alluvial land around the streams for cultivation of wild rice and gathering of aquatic resources such as fish, frogs, and so forth (Bayard 1971, 1984). Excavations during the 1960s revealed that Non Nok Tha functioned as a mortuary and intermittent industrial site, with little evidence for habitation (Bayard 1971, 1984). These findings and archaeological surveys suggest a dispersed settlement pattern of small hamlets and homesteads rather than a nucleated village (Bayard 1971, 1984; Wilen 1987, 1989). The mortuary

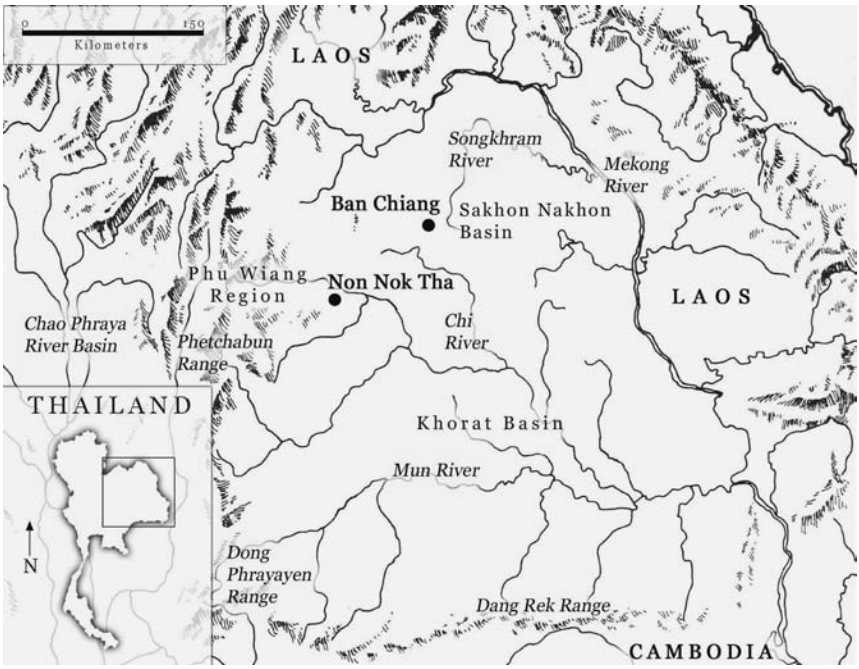

Figure 21.1. Detailed map showing the location of Non Nok Tha and Ban Chiang in northeastern Thailand.

Table 21.1. Archaeological Sequences in Northeastern Thailand

Non Nok Tha Chronology	Ban Chiang Chronology	Resource Base	Approx. Dates
	Late Period (IX–X)	Wet rice agriculture	2300–1800 BP
Middle Period (7–8)	Middle Period (VI–VIII)	Water buffalo; iron; gain in forest; frequent low-intensity burning	2900–1700 BP
Middle Period (4–6)	Early Period (III–V)	Hunter-gatherer-cultivator economy	4100–2900 BP
	Early Period (I–II)	Early bronze and domesticates; slow forest recovery from Middle Holocene	
Middle Period (1–3)		Hunter-gatherer-cultivator economy	5000–4000 BP
Early Period (1–3)		Premetal; domesticates incl. rice; evidence for large-scale burning	

Source: After Pietrusewsky and Douglas 2002b.
Note: The divisions for temporal subsamples (Early Group versus Late Group) are after Middle Period 3 at Non Nok Tha and after Early Period V at Ban Chiang.

remains come only from the first two periods (Early and Middle), dated to approximately 4500 BP to 2500 BP (Table 21.1). Domesticated pigs and cattle are present with the mortuary remains.

The village of Ban Chiang is located in the Songkhram drainage, northeast of Non Nok Tha, at an elevation of approximately 170 meters above sea level in an area of lowland soils suitable for rice agriculture. Excavations at Ban Chiang have recovered 141 inhumation burials from two separate locales (Gorman and Charoenwongsa 1976; White 1986). Three periods (Early, Middle, and Late) and ten phases were identified in the mortuary sequence, extending from approximately 4100 BP to 1800 BP. Sixth-millennium BP dates from the base of the site suggest that occupation preceded the mortuary evidence. Domesticated pigs, cattle, and dogs are present from the earliest mortuary phases at the site onward.

Chronological dating of subperiods at each site remains controversial (for example, Bayard 1996–97; Higham 1989, 1994); but our goal is to provide a chronological sequence of the burials. The skeletal series can be divided into temporal subsamples to provide a glimpse of human health and disease during the transition from hunting/gathering/cultivating toward intensified agriculture (Table 21.1). The Non Nok Tha skeletal series is divided between Middle Period 3 and Middle Period 4, separating burials from the premetal and very early Bronze Age from those of the later Bronze Age (Douglas 1996). The Ban Chiang skeletal series is divided between Early Period V and Middle Period VI, at approximately 2900 BP, coincident with technological and environmental changes.

Methods

The data presented here consist of selected paleodemographic indicators, dental pathological conditions (caries, antemortem tooth loss, periapical cavity, calculus, resorption, and attrition), linear enamel hypoplasia, cribra orbitalia, and stature, along with brief discussions of trauma and infectious disease. Each individual was examined using standard osteological methods (for details, see Douglas 1996; Pietrusewsky and Douglas 2002a). Statistical significance was determined using the chi-square test, Fisher's Exact Test, and Student's *t*-test (Thomas 1986).

Observations of the dentition are reported by tooth and by individual. An individual is defined as any burial possessing at least one tooth or alveolus. Caries rates are "corrected" (Lukacs 1995), but because these analyses did not distinguish between attrition and caries as the cause of pulp exposure, the procedure has been amended by using the number of teeth with sizeable carious lesions to estimate the proportion of teeth with pulp exposure attributable to caries (Domett 2001; Tayles et al. 2000).

Results

Age and sex distributions by temporal group for the skeletal series from Non Nok Tha and Ban Chiang (Tables 21.2 and 21.3) demonstrate fair representation of both sexes. As is typical with archaeological series, subadults are underrepresented at both locations.

NON NOK THA

The two temporal groups from Non Nok Tha (NNT) are equal in number, but the Late Group has fewer subadults less than 20 years of age (n=11) relative to the Early Group (n=31) (Table 21.2). A large number of individuals could be assigned only to broad categories (that is, adult, middle-aged, and subadult), suggesting that fertility-based paleodemographic estimators might be more useful than mortality-based estimators (Jackes 1992), though both are presented here (Table 21.4). The Early Group is characterized by high childhood mortality, with a life expectancy at birth of 27 years. The decreasing proportion of children suggests a decline in fertility over time. But improved life expectancy at birth (37 years) and an increase in mean age at death in the Late Group suggest that conditions improved over time.

The dental pathology profile in the adults (≥15 years of age) from NNT describes pathological conditions in the 66 percent (82/124) of the burials with dental remains, sex estimates, and phase assignments (Table 21.5). The most common pathological condition, by individual, is advanced calculus (56.1

Table 21.2. Age and Sex Distribution of Non Nok Tha Skeletons by Temporal Group

	Early Group (EP 1–3 to MP 1–3)				Late Group (MP 4–8)			
Age	M	F	?	T	M	F	?	T
Fetal							3	3
NB–0.9	3	2	2	7				
1–2.9	1	5		6				
3–4.9	5	1	1	7	2	2		4
5–7.9	2	1		3		1	3	4
8–9.9		1		1				
10–14.9		1	1	2	1		1	2
15–19.9		2		2	1			1
20–24.9	1	4		5		1		1
25–29.9		2		2	2	3		5
30–34.9	3	2		5	1			1
35–39.9	4	1		5	8	6		14
40–44.9	2	7		9	3	3		6
45–49.9	2			2	5	1		6
≥50	5	4		9	5	3		8
Adult	4	6	1	11	7	12	2	21
Middle-aged	2	2		4	1	6		7
Subadult			3	3				
Total	34	41	8	83	36	38	9	83

Note: Age is in years. NB = newborn; M = male; F = female; ? = unknown sex; T = total; EP = Early Period; MP = Middle Period. Burials with ambiguous temporal assignments are excluded from this table. When more accurate ages could not be estimated, individuals are listed under the following broad categories: subadult (<20 years of age), adult (20–50), young adult (20–35), and middle-aged (35–50).

Table 21.3. Age and Sex Distribution of Ban Chiang Skeletons by Temporal Group

	Early Group (EP I–V)				Late Group (MP VI–LP X)			
Age Interval	M	F	?	T	M	F	?	T
Fetal	1	2		3				
NB–0.9	1	2	3	6	2		1	3
1–2.9	1	1		2	1	2		3
3–4.9	2	2	4	8		2		2
5–7.9	2	1	1	4	1	1	1	3
8–9.9			1	1				
10–14.9	2			2				
15–19.9	1	1	2	4	2	1		3
20–24.9		2		2		2		2
25–29.9	3	4		7		1		1
30–34.9	1			1	1	1		2
35–39.9	5	4		9	3	2		5
40–44.9	4	2		6	1			1
45–49.9	9	4		13	1			1
≥50	1	2		3	1			1
Adult	6	3	1	10		4	2	6
Young adult		1		1	1	4		5
Middle-aged	7	4		11	5	3		8
Total	46	35	12	93	19	23	4	46

Note: Age is in years. NB = newborn; M = male; F = female; ? = unknown sex; T = total; EP = Early Period; MP = Middle Period; LP = Late Period. Burials with ambiguous temporal assignments are excluded from this table. When more accurate ages could not be estimated, individuals are listed under the following broad categories: adult (20–50 years of age), young adult (20–35) and middle-aged (35–50).

Table 21.4. Paleodemographic Features of the Early Group and Late Group Skeletons from Non Nok Tha

	Subadults[a]		**Adults**[a]		**Sex Distribution**[b]					
Sample	*n*	%	*n*	%	M	F	?	Ratio	E at Birth[c]	E at 15 Yrs[c]
Early	31	37.3	52	62.7	23	30	1	76.7	27.20	24.7
Late	11	13.8	69	86.3	33	35	2	94.3	37.44	26.9

	Mean Age at Death[d]	D20+/D5+[e]	JA Ratio[f]	MCM[g]	DR[h]	*N*[i]
Early	38.7	0.867	0.115	0.0465	0.84	83
Late	39.6	0.908	0.087	0.0320	0.29	80

[a] Subadults = individuals < 20 years of age (excludes fetal remains); adults ≥ 20 years of age.
[b] M = male; F = female; ? = unknown sex; sex ratio = proportion of adult (≥15 years of age) males to females (males/females × 100).
[c] E = life expectancy: calculated at birth and at 15 years of age (or nearest age to 15 in life table).
[d] Mean age at death in individuals ≥15 years of age.
[e] D_{20+}/D_{5+} = proportion of individuals who live beyond 20 years of age to those who survive the first 5 years of life.
[f] JA Ratio = juvenile-to-adult ratio, the ratio of individuals 5–14.9 years of age to those over 20 years of age (Jackes 1992, 1994).
[g] MCM = mean childhood mortality, the average of childhood mortality rates (5q5 5q10 5q15) (Jackes 1992, 1994).
[h] DR = Dependency Ratio: ratio of individuals <15 years of age plus those >50 years of age, over those 15–50 years of age (Howell 1982).
[I] *N* = total number of individuals used to construct the life table (fetal remains omitted).
[j] Early Group = burials from Early Period 1–3 and Middle Period 1–3.
[k] Late Group = burials from Middle Period 4–6.

percent), followed by antemortem tooth loss, or AMTL (40.2 percent). No statistically significant changes in individual dental pathology frequencies were found, but the trends are noteworthy. Caries, advanced alveolar resorption, AMTL, and advanced calculus increase, while advanced dental attrition is unchanged, and periapical cavities decline from Early Group individuals to Late Group individuals.

The tooth-count frequencies for all the variables except calculus are quite low, consistent with preagricultural communities (Lukacs 1989; Turner 1979). Unlike the individual frequencies, all of the tooth-count dental pathology frequencies increase over time, with statistically significant increases in AMTL, carious lesions (observed and corrected), and advanced alveolar resorption. Sex differences in dental pathology occur (that is, males display higher rates than females), but the dramatic temporal increases can be traced to an increase in dental pathologies in females (Douglas 2006, 1996: 426).

The individual rates and tooth-count rates of dental pathology reflect very similar but not identical trends through time, probably because the definition of an "individual" is very broad and because a few individuals can skew results in small samples.

Table 21.5. Dental Pathology Profile in Non Nok Tha Adults

	Adults				Individuals				Teeth			
	Indiv.		Teeth		Early Group		Late Group		Early Group		Late Group	
Disease	A/O	%	A/O	%	A/O	%	A/O	%	A/O	%	A/O	%
AMTL	33/82	40.2	125/1698	7.4	15/38	39.5	18/41	43.9	45/900*	5.0*	80/766*	10.4*
Observed Caries	19/79	24.1	34/1233	2.8	6/38	15.8	10/38	26.3	11/666*	1.7*	22/536*	4.1*
Corrected Caries[a]	30/79	38.0	47.3/1358	3.5	11/38	28.9	16/38	42.1	13.3/711*	1.9*	32.4/619*	5.2*
Periapical Cavity	12/78	15.4	27/1398	1.9	7/36	19.4	5/38	13.2	11/767	1.4	16/599	2.7
Calculus[b]	37/66	56.1	288/945	30.5	16/33	48.5	20/30	66.7	146/497	29.4	138/426	32.4
Resorption[b]	22/75	29.3	93/1022	9.1	8/34	23.5	13/37	35.1	39/540*	7.2*	53/454*	11.7*
Attrition[c]	17/80	21.3	76/1199	6.3	8/36	22.2	9/40	22.5	35/642	5.5	41/536	7.6

Note: Discrepancies between over all totals and period totals reflect individuals that could not be assigned to periods. Any burial with at least one tooth or tooth socket is counted as an individual. Adults are defined as individuals > 15 years of age. A = affected; O = observed; AMTL = antemortem tooth loss. Early Group includes burials from Early Period 1–3 and Middle Period 1–3; Late Group includes burials from Middle Period 4–6. None of the individual rate changes is statistically significant (p=.10). * indicates statistically significant differences (p=.05).

[a] Corrected caries rate after Lukacs (1995: 153), modified by Domett (2001: 123); see text.

[b] Advanced (moderate and marked).

[c] Advanced (pulp exposure or wear to roots).

The analysis of linear enamel hypoplasia (LEH) in NNT canines and incisors shows an overall temporal decline in both tooth-count and individual frequencies (Table 21.6). The decline is statistically significant in females.

The frequency of cribra orbitalia (CO) in NNT individuals with preservation of at least one orbit also declines over time (Table 21.7). No CO was found in the eleven subadults observed. Females were more often affected than males. Overall frequencies are quite low, but the individual sample sizes are also quite small.

Other indicators of skeletal stress include adult stature, skeletal trauma, and infectious disease. Mean adult statures increase over time at Non Nok Tha (Table 21.8). The increases are statistically significant in both sexes, although significance is dependent on the stature estimation formula utilized.

Table 21.6. Linear Enamel Hypoplasia in Non Nok Tha Adult Canines and Incisors

		Early Group[a]		**Late Group[b]**	
Element	Sex	A/O	%	A/O	%
Tooth					
Canines	Male	0/38	0.0	1/32	3.1
	Female	7/45	15.6	2/27	7.4
	Total	7/83	8.4	3/59	5.1
Incisors	Male	3/27	11.1	3/48	6.3
	Female	8/50*	16.0*	0/46*	0.0*
	Total	11/77*	14.3*	3/94*	3.2*
Individual	Male	2/13	15.4	2/15	13.3
	Female	5/18	27.8	2/16	12.5
	Total	7/31	22.6	4/31	12.9

Note: Linear enamel hypoplasia (horizontal lines and horizontal pits) only in all observable canines and incisors. Any burial with at least one canine or incisor is counted as an individual. Adults are defined as individuals at least 15 years of age. A = affected; O = observed.

[a] Burials from Early Period 1–3 and Middle Period 1–3.

[b] Burials from Middle Period 4–8.

* p=.05

Table 21.7. Cribra Orbitalia in Early and Late Group Individuals from Non Nok Tha

	Early Group[a]		**Late Group[b]**		**Total**	
Category	A/O	%	A/O	%	A/O	%
Males	2/14	14.3	0/17	0.0	2/31	6.5
Females	4/17	23.5	1/10	10.0	5/27	18.5
Total Adults	6/31*	19.4*	1/27*	3.7*	7/58	12.1
Subadults	0/9	0.0	0/2	0.0	0/11	0.0
Total	6/40	15.0	1/29	3.4	7/69	10.1

Note: A = number of affected individuals; O = number of individuals observed. Differences were tested using Fisher's Exact Test (FET) two tailed or chi-square (χ^2) statistic.

[a] Burials from Early Period 1–3, Middle Period 1–3.

[b] Burials from Middle Period 4–8.

* p=.10

Table 21.8. Mean Stature Estimates (in cm) in Non Nok Tha Adults

Sex	*N*	Early[a]	SD	*N*	Late[b]	SD	*t*-value
Based on Nonethnic Formulae							
Male	15	163.2	3.5	16	167.0[c]	5.6	2.2043*
Female	16	152.6	7.6	15	156.4	4.7	1.6803
Based on Thai-Chinese Formulae							
Male	15	164.7	2.4	16	166.5[c]	3.8	1.5633
Female	16	152.0	3.9	15	155.0	3.7	2.1986*

Sources: For nonethnic formulae, see Sjøvold 1990; for Thai-Chinese formulae, see Sangvichien et al. 1985, n.d.

Note: *N* = number of adults (≥18 years of age); SD=standard deviation. Mean stature estimates are based on complete bones only.

[a] Burials from Early Period 1–3, Middle Period 1–3.

[b] Burials from Middle Period 4–8.

[c] Late Group male burial 2-56 (humerus length 153.9 mm) removed from sample to lower SD/variance to meet equal variance assumption.

* p=.05

The frequency of trauma in the NNT skeletal series (Table 21.9) suggests that both males and females were active and susceptible to accidents, though all frequencies by element are under 7 percent. No evidence of traumatic injury was found in subadults. The most common injury in adults was fracture of a hand bone (three individuals), the clavicle (three individuals), the tibia (three individuals) or the ribs (three individuals). Traumatic injury was most common in MP 4 contexts (n=6)—at the transition to a more sedentary and more intensified form of subsistence economy. There is a nonsignificant increase in injury over time, with an increase in affected elements from 1.0 percent (9/920) in the Early Group to 1.3 percent (13/1012) in the Late Group and an increase in affected individuals from 12.3 percent (7/57) in the Early Group to 13.0 percent (9/69) in the Late Group. The absence of fractures typical of interpersonal violence, the random pattern of affected elements and types of fractures, and the lack of skull fractures (compare Lovell 1997; Walker 1989) suggest the absence of warfare or ritualized violence at Non Nok Tha.

Infectious disease is uncommon in the NNT skeletal series—less than 5 percent by element (Table 21.10). No infectious lesions were observed in subadults. Infectious lesions occurred in both males and females, and there is a statistically significant increase in lesions over time (χ^2=13.72, df=1), from 0.4 percent (2/564) of elements in the Early Group to 3.4 percent (16/476) of elements in the Late Group. The number of affected individuals also increases over time, from 2.3 percent (2/87) of the Early Group to 8.0 percent (7/87) of the Late Group. The most dramatic evidence for infection occurred in a female with complete collapse and fusion of the thoracic vertebrae (T3–T10), presumably reflecting tuberculosis or some other mycotic infection (Douglas

Table 21.9. Skeletal Injury in Non Nok Tha Adults

Element	EP 1–2 A/O Sex	EP 3 A/O Sex	MP 1–2 A/O Sex	MP 3 A/O	MP 4 A/O Sex	MP 5 A/O	MP 6 A/O Sex	MP 7 A/O	MP 8 A/O Sex	Total A/O	%
Parietal	1/8 M*	0/12	0/21	0/4	1/16 M*	0/8	0/8	0/2	0/0	2/79	2.5
Clavicle	0/5	1/12 F	1/22 F	0/5	1/20 M**	0/11	0/11	0/2	0/2	3/90	3.3
Scapula	1/9 M	0/10	0/18	0/6	0/17	0/12	0/9	0/2	0/4	1/87	1.1
Humerus—dist.	0/9	0/11	0/19	0/7	0/14	0/10	1/11 M	0/3	0/4	1/88	1.1
Radius—dist.	0/10	0/7	1/25 F	0/7	0/20	0/13	0/16	0/2	0/4	1/104	1.0
Metacarp	1/24 M*	0/30	0/78	0/21	1/67 M	0/56	0/39	0/9	0/14	2/338	0.6
Carpals	1/21 F	0/21	0/60	0/18	0/38	0/24	0/38	0/9	0/15	1/244	0.4
Tibia—mid.	0/10	0/6	0/28	0/10	1/33 M	0/14	1/14 F*	0/3	1/7 M	3/125	2.4
Fibula—mid.	0/11	0/2	0/17	0/6	0/26	0/15	1/11 F*	0/2	0/3	1/93	1.1
Vertebrae											
cervical	1/23 F*	0/21	0/35	0/16	1/44 M†	0/24	0/27	0/0	0/6	2/196	1.0
L5	0/0	0/3	0/7	0/2	2/6 F M†	0/6	0/5	0/1	0/1	2/31	6.5
Ribs	1/53 F*	0/34	0/100	0/36	2/90 M** M*	0/64	0/59	0/15	0/6	3/457	0.7
Affected ind.	4	1	2	0	6	0	2	0	1	16	
Sample size	10	8	32	7	28	14	17	4	6	126	12.7

Source: Adapted from Douglas 1996: 670–71.

Note: EP = Early Period; MP = Middle Period; LP = Late Period; M = male; F = female; dist. = distal; mid. = midshaft; Metacarp. = metacarpals; A = affected; O = observable; ind. = individuals. * , ** and † denote fractures occurring in the same individual. Sample includes all adults >15 years of age regardless of completeness. Counts are for the specific portion of the element given, right and left sides combined.

Table 21.10. Infectious Lesions in Non Nok Tha Adults and Subadults

Element	**EP 1–2**	**EP 3**	**MP 1–2**	**MP 3**	**MP 4**	**MP 5**	**MP 6**	**MP 7**	**MP8**	**Total**	
	A/O	A/O	A/O Sex	A/O	A/O Sex	A/O Sex	A/O	A/O	A/O Sex	A/O	%
Temporal	0/9	0/10	1/22 M	0/6	0/17	0/10	0/10	0/3	0/1	1/88	1.1
Ilium	0/10	0/7	0/16	0/7	1/10 F	2/11 M M	0/2	0/0	0/3	3/66	4.5
Tibia—distal	0/25	0/5	0/27	0/15	1/34 M	0/21	0/15	0/3	0/6	1/151	0.7
Vertebrae											
thoracic	0/80	0/52	1/105 F	0/47	2/104 M	0/64	0/44	0/8	9/14 F F*	12/518	2.3
lumbar	0/30	0/18	0/61	0/12	0/37	0/28	0/20	0/6	1/5 F*	1/217	0.5
Affected ind.	0	0	2	0	3	2	0	0	2	9	5.2
Sample size	28	11	38	10	34	20	20	6	7	174	

Source: Adapted from Douglas 1996: 484–85.

Note: EP = Early Period; MP = Middle Period; M = male; F = female; ind. = individuals. * indicates lesions occurring in the same individual. Sample includes all burials, adults (>15 years of age) and subadults. Counts are for the specific portion of the element given, right and left sides combined, except for the skull, which includes a complete or nearly complete unit.

1996; Pietrusewsky 1974). The appearance of these lesions in the later phases of the site implies an increase in sedentism, settlement density, or settlement duration.

In summary, the evidence for change over time in the NNT skeletal series is mixed. Life expectancy at birth increases, but mortality during childhood and for older subadults decreases, suggesting a decline in fertility that is inconsistent with expectations for the development and intensification of agriculture. The dental pathology results are consistent with a greater emphasis on dietary starches in the Late Group. Although rice appears to be less cariogenic than other grains such as maize (Tayles et al. 2000), the prehistoric diet at NNT may also have included millet and tuberous starches such as yams.

The relatively high frequency of advanced calculus suggests an alkaline oral environment, resulting from a high-protein diet or, indirectly, a high-carbohydrate diet; cultural behaviors such as betel nut chewing; water hardness; or silicon in the diet (Lieverse 1999). Sex differences in the dental pathology data (not shown) suggest differential access to food, differential oral behaviors, and/or sexual division of labor in which females were more closely associated with agricultural products than were males in the Late Group (Douglas 1996, 2006; Lukacs 1996).

The frequencies of linear enamel hypoplasia and cribra orbitalia both decline over time, and stature increases, suggesting an improvement in living conditions and/or nutrition in the Late Group at NNT. Trauma, although likely attributable to accidental injury, increases slightly over time and peaks at MP 4. There is an increase in infectious disease through time. Both of the latter trends are consistent with increased sedentism and intensifying agriculture at NNT.

BAN CHIANG

The sample sizes in the Early and Late Groups at Ban Chiang (BCH) are unequal, and the very small size of the Late Group complicates interpretations of temporal differences (Table 21.3). Nevertheless, the comparison is worth making, to see whether the trends revealed match those reported for other, larger skeletal series. Subadults are represented equally in both samples, but the sex ratio is skewed toward males in the Early Group and toward females in the Late Group (Table 21.11). This sex difference may be a result of sampling error or differential burial practices.

Paleodemographic parameters show a temporal decline in life expectancy at birth, in life expectancy at age 15, and in mean age at death. The birth rate (calculated as the inverse of life expectancy at birth) increases from the Early Group (33/1000) to the Late Group (36/1000), consistent with the increase in fertility that is expected with agricultural economies.

Table 21.11. Paleodemographic Features of the Early Group and Late Group Skeletons from Ban Chiang

	Subadults[a]		Adults		Sex Distribution[b]					
Sample	*n*	%	*n*	%	M	F	?	Ratio	E at Birth[c]	E at 15 Yrs[c]
Early[j]	27	30.0	63	70.0	37	27	3	137.0	30.4	24.4
Late[k]	14	30.4	32	69.6	15	18	2	83.3	28.1	20.8

	Mean Age at Death[d]	D20+/D5+[e]	JA Ratio[f]	MCM[g]	DR[h]	*N*[i]
Early	39.3	0.851	0.111	0.052	0.52	90
Late	35.8	0.842	0.094	0.055	0.48	46

[a] Subadults = individuals < 20 years of age (excludes fetal remains); adults ≥ 20 years of age.
[b] M = male; F = female; ? = unknown sex; sex ratio = proportion of adult (≥15 years of age) males to females (males/females × 100).
[c] E = life expectancy: calculated at birth and at 15 years of age (or nearest age to 15 in life table).
[d] Mean age at death in individuals ≥15 years of age.
[e] D_{20+}/D_{5+} = proportion of individuals who live beyond 20 years of age to those who survive the first 5 years of life.
[f] JA Ratio = juvenile-to-adult ratio, the ratio of individuals 5–14.9 years of age to those over 20 years of age (Jackes 1992, 1994).
[g] MCM = mean childhood mortality, the average of childhood mortality rates (5q5 5q10 5q15) (Jackes 1992, 1994).
[h] DR = Dependency Ratio: ratio of individuals <15 years of age plus those >50 years of age, over those 15–50 years of age (Howell 1982).
[I] *N* = total number of individuals used to construct the life table (fetal remains omitted).
[j] Early Group = burials from Early Period I–V.
[k] Late Group = burials from Middle Period VI–Late Period X.

The fertility-based estimators are mixed; the decline in the juvenile-to-adult ratio suggests a decline in fertility, but the increase in mean childhood mortality suggests an increase in fertility (Jackes 1992, 1994). The D_{20+}/D_{5+} ratio also declines slightly over time, suggesting an increase in fertility.

The BCH dental sample includes 63 individuals, 94 percent (63/67) of adults at least 15 years of age, comprising those with dental remains, sex estimates, and phase assignments (Table 21.12). Tooth-count frequencies of many of the dental pathology variables at BCH fall in the range of "preagricultural or mixed economies" populations (Lukacs 1989; Turner 1979). The most common pathological condition is advanced calculus (identified in 49.2 percent of individuals), followed by antemortem tooth loss and caries (46.0 percent each). With the exception of periapical cavities, individual frequencies suggest improving dental health over time.

Dental pathology measured by tooth-count does not follow the general improvement trend suggested for individuals. Statistically significant increases in periapical cavities and advanced calculus are mirrored in a general trend

Table 21.12. Dental Pathology Profile in Ban Chiang Adults

	Adults				Individuals				Teeth			
	Individuals		Teeth		Early Group		Late Group		Early Group		Late Group	
Disease	A/O	%	A/O	%	A/O	%	A/O	%	A/O	%	A/O	%
AMTL	29/63	46.0	89/1324	6.7	21/43	48.8	8/20	40.0	64/1012	6.3	25/312	8.0
Observed Caries	29/63	46.0	70/1061	6.6	23/43*	53.5*	6/20*	30.0*	60/826*	7.3*	10/235*	4.3*
Corrected Caries[a]			77.7/1150	6.8					66.5/890	7.5	11.1/260	4.3
Periapical Cavity	21/60	35.0	66/1084	6.1	14/43	32.6	7/17	41.2	44/850**	5.2**	22/234**	9.4**
Calculus[b]	30/61	49.2	253/918	27.6	23/42	54.8	7/19	36.8	158/663**	23.8**	95/255**	37.3**
Resorption[b]	22/55	40.0	116/896	12.9	17/39	43.6	5/16	31.3	92/657	14.0	24/239	10.0
Attrition[c]	28/63	44.4	169/1061	15.9	20/43	46.5	8/20	40.0	124/754	16.4	45/307	14.7

Note: Any burial with at least one tooth or tooth socket is counted as an individual. Adults are defined as individuals >15 years of age. A = affected; O = observed; AMTL = antemortem tooth loss. Early Group includes burials from Early Period I–V; Late Group includes burials from Middle Period VI–Late Period X.

[a] Corrected caries rate after Lukacs (1995: 153) modified by Domett (2001: 123); see text.

[b] Advanced (moderate and marked).

[c] Advanced (pulp exposure or wear to roots).

* p=.10 ** p=.05

Table 21.13. Linear Enamel Hypoplasia in Ban Chiang Adult Canines and Incisors

		Early Group		Late Group	
Element	Sex	A/O	%	A/O	%
Tooth					
Canines	Male	9/50	18.0	4/16	25.0
	Female	9/55	16.4	1/28	3.6
	Total	18/105	17.1	5/44	11.4
Incisors	Male	11/75	14.7	1/19	5.3
	Female	5/74*	6.8*	4/18*	22.2*
	Total	16/149	10.7	5/37	13.5
Individual	Male	6/19	31.6	3/9	33.3
	Female	7/20	35.0	1/6	16.7
	Total	13/39	33.3	4/15	26.7

Note: Linear enamel hypoplasia (horizontal lines and horizontal pits) only in all observable canines and incisors. Any burial with at least one canine or incisor is counted as an individual. Adults are defined as individuals at least 15 years of age. A = affected; O = observed.

[a] Burials from Early Period I–V.

[b] Burials from Middle Period V–Late Period X.

* p=.05.

of increased antemortem tooth loss. The frequency of carious teeth declines, however, along with the frequencies of advanced alveolar resorption and advanced attrition. This suggests that the likely cause for antemortem tooth loss in the BCH dental remains was periodontal disease rather than caries.

In contrast to Non Nok Tha, sex differences in the Ban Chiang dental pathology profiles are smaller (data not shown). The significant increase in periapical cavities in the Late Group reflects an increase in male alveoli (5.2 percent to 13.1 percent) rather than female alveoli (5.2 percent to 2.5 percent). Both sexes have a statistically significant increase in advanced calculus, which may reflect an increase in dietary protein or carbohydrates, or a change in oral behaviors such as betel nut chewing.

The frequencies of linear enamel hypoplasia (LEH) in BCH canines and incisors exhibit mixed results by sex over time (Table 21.13). LEH increases in male canines but decreases in male incisors; the opposite is true for females. The individual frequency of LEH increases over time in males and decreases over time in females, though the trends are not statistically significant. When the sexes are combined, there is a slight decrease in LEH frequency by tooth (canines and incisors combined) and a decrease in LEH frequency by individual.

Evidence for iron-deficiency anemia, inferred from the presence of cribra orbitalia (CO), was noted in 25 percent of BCH adults and subadults (Table 21.14). In the Early Group, five out of nine subadults were affected (55.6 per-

cent) and no adult males were affected (0/14). In the Late Group, fewer subadults were affected (16.7 percent), but the increase in affected adult males results in a statistically significant increase in CO in adults (8.7 percent to 40.0 percent). Female rates of CO remain stable over time.

Mean adult stature estimates increase over time in both sexes from Ban Chiang (Table 21.15), suggesting an increase in caloric intake and/or a relaxation of other stressors on subadult growth.

Skeletal trauma was present in twenty BCH adults: eight females and twelve males (Table 21.16). The most commonly fractured bones were the ribs (five individuals) and lumbar vertebrae (four individuals). There were no patterns of injury that suggest interpersonal violence or warfare (compare Lovell 1997; Walker 1989). The pattern of fractures that were found primarily suggests a strenuous lifestyle with accidental injury. There is no change in traumatic in-

Table 21.14. Cribra Orbitalia in Early and Late Group Individuals from Ban Chiang

	Early Group[a]		**Late Group[b]**		**Total**	
Category	A/O	%	A/O	%	A/O	%
Males	0/14	0.0	2/4	50.0	2/18	11.1
Females	2/9	22.2	2/6	33.3	4/15	26.7
Total Adults	2/23*	8.7*	4/10*	40.0*	6/33	18.2
Subadults	5/9	55.6	1/6	16.7	6/15	40.0
Total	7/32	21.9	5/16	31.3	12/48	25.0

Note: A=number of affected individuals; O=number of individuals observed. Differences were tested using Fisher's Exact Test (F) two tailed or chi-square (χ^2) statistic.
[a] Burials from Early Period I–V.
[b] Burials from Middle Period VI–Late Period X.
* p=.10

Table 21.15. Mean Stature Estimates (in cm) in Ban Chiang Adults

Sex	*N*	Early[a]	SD	*N*	Late[b]	SD	*t*-value
Based on Nonethnic Formulae							
Male	17	166.3	5.7	12	167.5	4.9	0.5522
Female	17	156.5	8 7	7	158.3	5.0	0.9472
Based on Thai-Chinese Formulae							
Male	17	165.4	3.6	12	166.0	3.7	0.4373
Female	17	153.9	3.2	7	154.4	2.6	0.3278

Sources: For nonethnic formulae, see Sjøvold 1990; for Thai-Chinese formulae, see Sangvichien et al. 1985, n.d.
Note: Mean stature estimates are based on complete bones only. *N* = number of adults (≥18 years of age) with observable long bone elements; SD=standard deviation. None of the results are statistically significant at p=.10.
[a] Burials from Early Period I–V.
[b] Burials from Middle Period VI–Late Period X.

Table 21.16. Skeletal Injury in Ban Chiang Adults

Sample	EP I–II A/O Sex	EP III A/O Sex	EP IV A/O Sex	EP V A/O Sex	MP VI A/O Sex	MP VII A/O Sex	LP IX–X A/O Sex	Total A/O	Total %
Frontal	0/4	0/4	1/16 M*	0/12	1/2 M*	0/9	0/2	2/49	4.1
Hyoid	0/0	0/0	0/2	0/0	0/1	1/1 M*	0/0	1/4	25.0
Scap.—glen.	0/4	0/8	0/13	0/17	0/3	1/9 M*	0/4	1/58	1.7
Humerus									
distal	0/5	0/7	1/13 F	0/16	0/6	0/13	0/6	1/66	1.5
midshaft	0/12	0/9	0/16	1/20 M	0/4	0/10	0/6	1/77	1.3
Radius									
proximal	0/3	0/6	1/14 F	0/14	0/3	0/11	0/4	1/55	1.8
distal	0/9	0/9	1/15 F	0/24	0/7	0/12	0/10	1/86	1.2
Metacarp	0/25	1/36 M	0/63	0/85	0/15	1/49 M	0/18	2/291	0.7
Carpals	0/1	0/3	0/11	0/12	0/3	0/6	1/3 M	1/39	2.6
Femur—mid.	0/11	0/9	0/18	1/23 M	0/6	0/9	0/10	1/86	1.2
Tibia									
proximal	0/10	1/10 M*	1/16 M†	0/23	0/10	0/18	0/7	2/94	2.1
distal	0/5	0/8	0/13	0/14	0/5	0/12	1/7 F	1/64	1.6
Metatars.	0/27	0/32	0/73	0/47	0/19	1/52 M*	0/11	1/261	0.4
Vertebrae									
cervical	0/8	0/18	2/25 M*	0/56	1/12 M*	0/29	0/9	3/157	1.9
L4 & L5	1/2 F	0/8	1/14 M†	3/13 F* F	0/4	0/11	0/3	5/55	9.1
Ribs	0/15	2/64 M*	4/83 M F	1/117 F*	0/12	3/80 M	0/28	10/399	2.5
Affected ind.	1	2	7	4	1	3	2	20	
Sample size	13	9	16	29	8	17	9	101	

Note: EP = Early Period; MP = Middle Period; LP = Late Period; M = male; F = female; Scap. = scapula; glen. = glenoid; Metacarp. = metacarpals; mid. = midshaft; Metatars. = metatarsals; A = affected; O = observable; ind. = individuals. There were no adult burials from MP VIII. Burials with a two-phase range (such as EP II–III) are placed in the later phase; burials with a larger phase range (that is, Phase II–IV) are omitted. One burial with an MP phase range is shown in MP VII. * and † denote fractures occurring in the same individual. Sample includes all adults 15 years of age or older, regardless of completeness. Counts are for the specific portion of the element given, right and left sides combined. For details see Pietrusewsky and Douglas 2002a: 101–3.

jury over time: 1.8 percent (23/1270) of skeletal elements were affected in the Early Group, and 1.9 percent (11/571) of skeletal elements were affected in the Late Group.

Evidence for infectious disease in the BCH skeletal series, found in both adults (n=11) and subadults (n=5), is most common in EP IV (Table 21.17). There was no evidence of tuberculosis, treponemal disease, or other systemic, endemic infection. There is no change in the element frequency of infection over time (1.7 percent versus 1.7 percent), but there is an increase in the individual frequency of infection, from 11.0 percent (9/82) in the Early Group to 15.6 percent (7/45) in the Late Group ($p \leq 1.0$). }

In summary, the BCH skeletal series provides enigmatic evidence for health effects of intensifying agriculture. Though there is an apparent temporal in-

Table 21.17. Infectious Lesions in Ban Chiang Adults and Subadults

Element	EP I–II	EP III	EP IV	EP V	MP VI	MP VII	MP VIII	LP IX-X	Total	
	A/O	A/O	A/O Sex	A/O Sex	A/O Sex	A/O Sex	A/O Sex	A/O Sex	A/O	%
Skull	0/3	0/4	2/8 S S	0/6	0/1	0/6	0/0	0/2	2/30	6.7
Frontal	0/9	0/7	0/21	0/13	0/2	0/13	2/2 S	0/3	2/70	2.9
Parietal	0/8	0/10	1/15 M*	0/9	0/3	0/15	0/1	1/6 F	2/67	3.0
Occipital	0/6	0/8	0/23	0/11	0/4	2/16 S	0/2	0/7	2/77	2.6
Temporal	0/7	0/17	3/27 F M	0/14	1/5 M	1/16 M	0/2	0/4	5/92	5.4
Hand—phalanx	0/21	0/22	0/68	1/96 M*	0/18	0/61	0/2	0/46	1/334	0.3
Ilium	0/4	0/7	1/15 M*	1/10 F	0/5	0/6	0/0	0/3	2/50	4.0
Femur—shaft	0/18	0/14	2/32 S†	0/25	0/7	0/13	0/0	0/15	2/124	1.6
Tibia—shaft	0/15	0/15	2/23 S†	1/26 M	0/12	1/20 M	0/6	1/13 F	5/130	3.8
Ribs	0/41	0/77	0/166	4/121 M*	0/13	0/125	0/16	0/52	4/611	0.7
Affected ind.	0	0	6	3	1	3	1	2	16	12.6
Sample size	22	9	19	32	9	21	1	14	127	

Note: EP = Early Period; MP = Middle Period; LP = Late Period; M = male; F = female; S = subadult (<15 years of age); ind. = individuals. Burials with a two-phase range (such as EP II–III) are placed in the later phase, burials with a larger phase range (that is, Phase II–IV) are omitted. * and † denote lesions occurring in the same individual. Sample includes all burials, adults and subadults. Counts are for the specific portion of the element given, right and left sides combined, except for the skull, which includes a complete or nearly complete unit. For details see Pietrusewsky and Douglas 2002a: 123.

crease in fertility, the BCH life expectancy at birth and the mean age at death decline over time. Trends in dental pathology are mixed, with a decrease in the frequencies of carious lesions, advanced attrition, and alveolar resorption in the Late Group but an increase in the frequencies of antemortem tooth loss, periapical cavities, and calculus. Among adults the frequency of linear enamel hypoplasia is stable, but the frequency of cribra orbitalia and mean stature estimates increase in the Late Group. The frequencies of traumatic injury and infectious disease exhibit only slight, statistically nonsignificant changes over time.

Discussion

Evidence reported elsewhere (see introduction) suggests a general global decline in health with increased sedentism and/or the adoption and intensification of agriculture (for example, Cohen and Armelagos 1984; Larsen 1995, 1997). Typically, with these transitions there are increases in fertility, caries, linear enamel hypoplasia, cribra orbitalia, trauma, and infectious disease, while mean age at death, dental attrition, and stature all decline. Southeast Asia appears to be one region that exhibits significant local variation in the timing and the degree of impact of sedentism and agriculture on human health (for example, Oxenham 2000; Pietrusewsky and Douglas 2002b; Tayles 1999). Comparisons of some prehistoric skeletal series from southeastern and north-

eastern Thailand suggest an improvement in health over time (Domett 2001; Nelson 1999). The reasons for the difference between Southeast Asia and other regions might include the relatively high nutritive value and low cariogenicity of rice relative to other cultigens (Tayles et al. 2000); the late commitment to intensified (wet rice) agriculture; and sustained broad-spectrum foraging even with agriculture.

The Non Nok Tha and Ban Chiang skeletal series are good examples of this regional variation. From the beginnings of the mortuary sequences at both sites, there is evidence for rice, domesticated dogs, pigs, and cattle; pottery; and a variety of other land and aquatic plant and animal resources (such as birds, deer, hare, fish, frogs, turtle, and so forth). Ethnographic analogy suggests that indigenous resources available today are likely to have been available in the past, including fruits, beans, gourds, and nuts (White 1986, 1995).

The archaeological evidence at Non Nok Tha suggests a less sedentary or less nucleated population than at Ban Chiang. Small groups of people contributed their dead to the mound but did not reside there. Domesticated animals were readily available and plentiful during the early mortuary phases of the site, suggesting some degree of stability by at least a segment of the population. The evidence for metal (bronze) technology at Non Nok Tha first appears in EP 3, casting evidence appears in MP 1–2, and an ornament appears in MP 3, but the use of bronze does not seem to have had a major impact on the society. Both accidental and stress-related injury, in both males and females, at Non Nok Tha indicates a risky physical lifestyle. Dental pathology suggests increased emphasis on starches in the later phases, primarily in females, which implies differential access or a sexual division of labor in which females were more sedentary and closer to the agricultural products than males. The increase in starches may also reflect an increase in caloric intake that would help explain the increase in stature over time. The frequencies of linear enamel hypoplasia and cribra orbitalia decline over time, which suggests improved childhood conditions that may also have contributed to increased adult stature. Finally, the presence of at least one case of probable tuberculosis in the later mortuary phases at Non Nok Tha is consistent with increased sedentism.

At Ban Chiang, the archaeological evidence supports a more or less continuous, sedentary settlement. Domesticated animals were present. A bronze spear point was recovered from a grave in EP III, and bronze bracelets were recovered from a grave in EP IV. Iron appears in MP VII. Iron and water buffalo for traction assist in the intensification of paddy-field rice agriculture.

The skeletal evidence from Ban Chiang suggests a decline over time in life expectancy and mean age at death. The fertility estimators are mixed, reflecting both an increase and a decrease in fertility, likely because of sampling error

and the underrepresentation of subadults. Although there is a decline in caries, other dental pathologies increase. The frequency of linear enamel hypoplasia remains fairly constant, but there is an increase in adult cribra orbitalia in the later phases. This increase suggests increased childhood stress, yet adult stature also increases. Traumatic injury, including both stress-related fractures (for example, spondylolysis) and accidental injury, suggests a risky physical lifestyle for both sexes throughout the Ban Chiang mortuary sequence. There is a trend toward increased infectious lesions beginning in EP IV, which could reflect an increase in settlement density, exposure to new pathogens, and/or poor sampling in the earlier mortuary phases.

The archaeological, environmental, and subsistence evidence suggests that the skeletal series from Non Nok Tha should have lower levels of stress indicators than the skeletal series from Ban Chiang, and that is true for the majority of the indicators. In fact, the Early Group at Ban Chiang is very similar to the Late Group at Non Nok Tha, so there is an overlapping continuum between the two sites over time, as well as a continuum in paleopathological indicators consistent with a slow intensification of agriculture in the region. Together, these two sites document variation in the biological response to sedentism and the slow transition from hunting, gathering, and cultivating to intensified agriculture.

22

Editors' Summation

MARK NATHAN COHEN AND GILLIAN M. M. CRANE-KRAMER

The data reported here summarize changes in skeletal pathology accompanying prehistoric and historic economic and political change in twenty-one regions of the world, many of which are little known in the paleopathological literature. The data are summarized in this chapter and graphically represented in fifteen two-part figures. In the interest of brevity, patterns are described here without the caveats and modifiers applied in each chapter. We consider the cemetery samples roughly representative of the populations from which they were derived (see Appendix A).

Summary of Chapters

Cook discusses early maize agriculture in the American Midwest and both discusses and challenges the common assumption equating periosteal inflammation with infection. She then assesses the difficulties of making a differential diagnosis of tuberculosis in relation to the disease epidemiology, and she reiterates the late occurrence of TB.

Larsen and colleagues describe Georgia and Florida populations between 2400 BP and AD 1700. Health generally declined, but significant regional variation is exhibited in the patterns of various health indicators. Infection, including treponemal infection, increased over time. LEH increased in most areas. Stature declined in Georgia. The worst health occurred in postcontact missionized populations because of increased dependence on maize, increased density of mission settlements, and introduced diseases. Caries and PH increased with missionization. LEH occurred less frequently (but the hypoplasias are broader) after contact, but under microscopic analysis, Wilson bands could be observed in an increasing percentage of the population. Mechanical stress on bones declined with incipient agriculture but increased with missionization.

Doran describes Archaic Period Windover in Florida, circa 7400 BP, comparing it to other Archaic and later sites in North America. Despite great regional diversity, Archaic populations tended to be relatively tall, suffering less disease than in later periods. CO, PH, and trauma increased over time.

Hutchinson and colleagues describe populations reflecting ecological and temporal differences in the adoption of agriculture on the North Carolina coast between 2300 and 350 BP. Tiny Middle Woodland and larger Late Woodland populations on the inner and outer coasts were compared, with some exhibiting indicators of declining health. Caries were high in the earlier group, but PH, treponemal infection, and osteoarthritis occurred only in the later groups. The incidence of LEH remained unchanged.

However, the regional comparisons made by Hutchinson and colleagues overshadow the temporal ones. Inner coastal populations adopted maize, yet PH was more common among adults of the outer coastal region (perhaps reflecting parasite load) but more common among children inland (perhaps reflecting weaning to a maize diet). Periostitis (perhaps attributable to treponemal infections) was more common in the outer coastal population. Vertebral osteoarthritis was more common among the inner coastal farmers. LEH was more common in inner coastal populations in both periods but was particularly marked in Late Woodland subadults.

Danforth and colleagues describe health trends between circa 7000 BP and 500 BP in several regions in the south-central United States. The later, Mississippian sites tend to be represented by elites, who generally display lower rates of pathology than commoners, making health in these sites appear better than it should when compared to earlier sites. Infection increased through time. TB and treponemal infection were found in later sites. Osteoarthritis declined over time. Stature increased significantly for females in the Delta and in western Tennessee and for both sexes in northern Alabama. Caries and abscesses increased over time. Anemia generally was uncommon. LEH declined through time in the Delta. Tooth attrition was high in all periods. On the Gulf Coast, Woodland and Mississippian populations were of equal stature and displayed equally low rates of anemia. Rates of hypoplasia show a slight but insignificant increase.

Márquez Morfín and colleagues (2002) have elsewhere described a pattern of declining health from early farming villages to later sites and centers in Mesoamerica between 3500 and 1750 BP. In this volume, Márquez Morfín and Storey expand the discussion, emphasizing lowland/highland distinctions and issues of social complexity. The lowlands showed greater morbidity through time. PH increased in lowland areas but decreased in the highlands. Caries increased over time, as did LEH, tibial inflammation/infection, and trauma. Auditory exostoses declined.

Pechenkina and colleagues report on populations from the Peruvian central coast between 6500 and 1000 BP, spanning the transition from hunting-and-gathering groups gradually accumulating cultigens, to farming communities marked by social hierarchies in varied environments. Most health indica-

tors—including caries, stature, PH, and LEH—suggest relatively good health among the population of the earliest site (Paloma). Health declined thereafter. Treponemal infection was relatively frequent in children in the earlier periods, declining thereafter, and adults became the primary victims, perhaps reflecting a shift in treponemal infection from a nonvenereal yaws-like disease to venereal syphilis. Tuberculosis appears only in skeletal materials from the later periods.

Alfonso and colleagues report a transition from coastal Archaic foragers to coastal and inland populations displaying complex social organization in the Azapa Valley of Chile between 9000 and 1000 BP. Rates of LEH, caries, alveolar resorption, and AMTL generally increase through time, but the incidence of tooth wear and abscesses declines. CO and PH were common early in coastal groups, a pattern associated with marine parasites. Quality of life declined inland but not in coastal regions.

Bennike and Alexandersen discuss populations in southern Scandinavia from 11,000 to 3700 BP. Possible genetic mixing/immigration complicate interpretations. Stature and tooth size (both deciduous and permanent) declined from the Paleolithic to the Early Neolithic, as a result of declining health and nutrition. Stature rebounded to its highest level in the later Neolithic, then declined. AMTL and caries generally increased over time, but dental attrition and bone and cranial robusticity declined. LEH and trauma, common in the Mesolithic and Early Neolithic, were slightly lower thereafter. Elsewhere, Bennike (1985) has described increasing rates of infection including treponemal disease, leprosy, and TB.

Roberts and Cox trace health in Britain from the Neolithic, circa 6000 BP, through the mid-nineteenth century AD using both paleopathological and historic records. They found an irregular but generally declining pattern of health through time. Infection—particularly TB, leprosy, and syphilis—generally increased through time. LEH, stature, caries, and CO tend to have increased in the Bronze Age, decreased in the Iron Age, and increased in the Roman period. Stature increased for males in the Roman period but declined for females. Caries and CO tend to have declined in the Early Medieval period, but LEH increased, as did stature. In the Late Medieval period, CO and LEH increased and stature decreased; and in the Post-Medieval period, LEH and CO declined, caries increased, and stature increased for females.

Cunha and colleagues compare Mesolithic hunter-gatherers and Final Neolithic/Chalcolithic populations from Portugal between 4700 and 3900 BP. Dental attrition declined through time, but caries increased. Trauma showed little change in frequency. Degenerative change increased over time, as did infection.

Littleton describes populations from the Bronze Age through the Iron Age,

Hellenistic, and Islamic periods between 4200 and 500 BP in Bahrain, a period marked by changing natural ecology, politics, and trade, as well as subsistence. The Bronze Age population displayed moderate CO and PH and little evidence of nutritional shortage. PH increased over time, but CO was more common in the earlier Bronze Age and Iron Age. The Hellenistic period was a low point in health, exhibiting high rates of anemia and rickets. LEH increased (particularly in subadults) and appeared at earlier ages. Apparently, both adult and subadult mortality increased. A major factor in declining health appears to have been increased infectious disease (probably malaria, among others) related to intensification of agriculture. Although stature changed little among males, female stature and robusticity declined significantly in the Iron Age and Hellenistic period. Female and male stature rebounded in the pre-Islamic period.

Blau reports on populations from the United Arab Emirates between the sixth and second millennia BP. Dental pathologies display a mixed and complex pattern. Dental wear, abscesses, and calculus tend to have become less common and/or less severe through time. Caries rates and AMTL tend to have increased. However, lacking articulated skeletons, Blau cannot correct for the age of individuals. High rates of trauma, infection, and CO occurred not at the latest sites for which skeletal data were recorded but at earlier sites, which have evidence of larger and more complex societies, monumental architecture, and possible fortification. These pathologies tend to decline as social complexity declines. LEH shows the opposite trend, generally increasing in later periods.

Smith and Horwitz describe evolving economies from hunting and gathering to agropastoralism in the Southern Levant between circa 13,000 and 7500 BP. Health began to decline beginning in the Late/Final Natufian and Pre-Pottery Neolithic A, with the adoption of incipient farming. Stature, tooth size, and cranial and facial robusticity declined, whereas caries, dental attrition, AMTL, and LEH increased.

Increasing use of domesticates produced a period of improved health in the Pre-Pottery Neolithic B, marked by an increase in male stature and a decline in LEH. However, mandibles and teeth declined in size, and attrition and abscesses were severe. Smith and Horwitz report a significant decline in health in the Late and Final Pre-Pottery Neolithic B (also identified as Pre-Pottery Neolithic C, or PPNC). CO became more common, arthritis was common, and caries and AMTL increased. LEH was both common and severe and was found at younger ages than before. Robusticity increased, but there was a decrease in female cortical thickness. Female stature reached an all-time low. This pattern of relative ill health continued and was exacerbated in later periods. Increasing rates of infection probably reflect zoonoses introduced by newly domesticated animals. Specific infections appearing for the first time in the PPNC include TB as well as possible malaria and meningeal encephalitis.

Pfeiffer, describing hunter-gatherer populations in southern Africa between 13,000 BP and the historic period, found no infection or periostitis in the entire sequence. Rates of PH, Harris lines, CO, and osteoarthritis are low to moderate. In the sample populations, fractures are rare, dental attrition is heavy, and people and teeth are small (but teeth become even smaller during the historic period). Skeletons display low rates of PH, slight to moderate CO, and moderate Harris lines (peaking, surprisingly, between ages six and twelve). There are irregularities but few consistent trends.

Lukacs confirms Kennedy's (1984) assessment of declining health in prehistory in India. He also describes a reverse transition from farming to hunting and gathering (circa 3400–2700 BP) at one site, Inamgaon, accompanied by indicators of improving health. Caries rates in adults decline, although those of subadults do not change. In the analyzed samples, permanent—but not deciduous—teeth become larger (which is seen as evidence of improving nutrition), and deciduous—but not permanent—teeth display declining rates of LEH. As farmers reverted to foraging, their health improved.

Bazarsad describes a decline in CO and a possible improvement in health between earlier herders and later herder-nomads in Mongolia between 2900 and 1900 BP, but the trend may reflect the fact that the later population had access to the resources of neighbors they dominated politically.

Pechenkina and colleagues describe health trends in China between 9000 and 1800 BP, from the Peiligang period through the Yangshao and Longshan periods to the Han Dynasty. Stature declined through the sequence. Although variation between sites was evident, caries rates generally increase but abscesses, AMTL, and calculus accretion show no clear trend. Mandibular tori, maxillary exostoses, and temporomandibular problems declined. PH was moderate initially, then declined during the Yangshao period but reached its highest level in the later periods. LEH rates, varied at Yangshao sites, were generally higher at later sites. In general, health showed little variation within the Yangshao Neolithic but began to decline in later periods.

Krigbaum describes gradual economic evolution from the pre-Neolithic to the Neolithic in Malaysia, circa 4500–3000 BP. No clearly defined economic transition occurred; rather, broad-spectrum foraging continued through the sequence. Fragmentary evidence leaves the impression of low levels of pathology throughout the sequence with little change. A cited report suggests that LEH is common but shows no trend through time. Stature declined and caries and AMTL increased through time.

In a paper presented to the conference but not published here (Oxenham 2004), sedentary foragers are compared with protohistoric metal age populations, between 6000 and 2000 BP. In this study, rates of LEH, CO, caries,

and trauma remain approximately constant, but infectious disease clearly increased in the later period.

Domett and Tayles report on populations from two sites in Thailand, Ban Lum Khao and Noen U-Loke, from the Bronze to the Iron Age (circa 3400 to 1600 BP); their findings suggest a gradual improvement in health, indicated by increasing stature among men and declining LEH. However, rates of infection, including major diseases such as TB and leprosy, increase. Rates of dental abscesses and attrition increase in the later site; caries remain unchanged. Mortality patterns display an interesting difference in the distribution of deaths. The former site displays lower infant mortality but high levels of juvenile mortality, peaking between 5 and 9 years of age. At the latter site, the proportion of infant and child mortality is reversed. Rates of female mortality, particularly in the younger categories, decline over time.

Douglas and Pietrusewsky describe a mixed pattern but one that suggests an overall improvement in health between hunting-and-gathering groups with some cultivation and rice agriculturalists from two sites in Thailand dated between circa 5000 and 1800 BP. An increase over time in alveolar resorption, caries, and AMTL, particularly among females, is evident at Non Nok Tha. High rates of calculus are evident. LEH and CO declined over time. Stature increased over time for both sexes, but infection increased over time, with TB appearing only late in the sequence. Douglas and Pietrusewsky describe an increase in mean age at death through time, which implies improved conditions.

At Ban Chiang, high rates of calculus occur; attrition, caries, and alveolar resorption decreased through time, but abscesses and AMTL increased. CO decreased in subadults but increased in adult males. Stature increased for both sexes. The frequency of infection increased. Frequencies of LEH show mixed trends, depending on both sex and tooth studied.

Summary by Pathology

Data illustrating trends in each pathology in each region, aligned on a common time scale, are summarized in Figures 22.1–22.15. No quantitative comparisons between regions are implied. Slopes are not precise. Breakdown of results by subregion, sex, or age is limited by space. Coverage of different pathologies differs markedly among regions. LEH is discussed in 19 of the sequences; dental caries in 17; infection in 16; CO in 13; stature in 13; specific diseases in 13; trauma in 11; AMTL in 11; dental attrition in 11; PH in 10; osteoarthritis in 9; abscesses in 7; skeletal robusticity in 7; tooth size in 5; and alveolar resorption in 4.

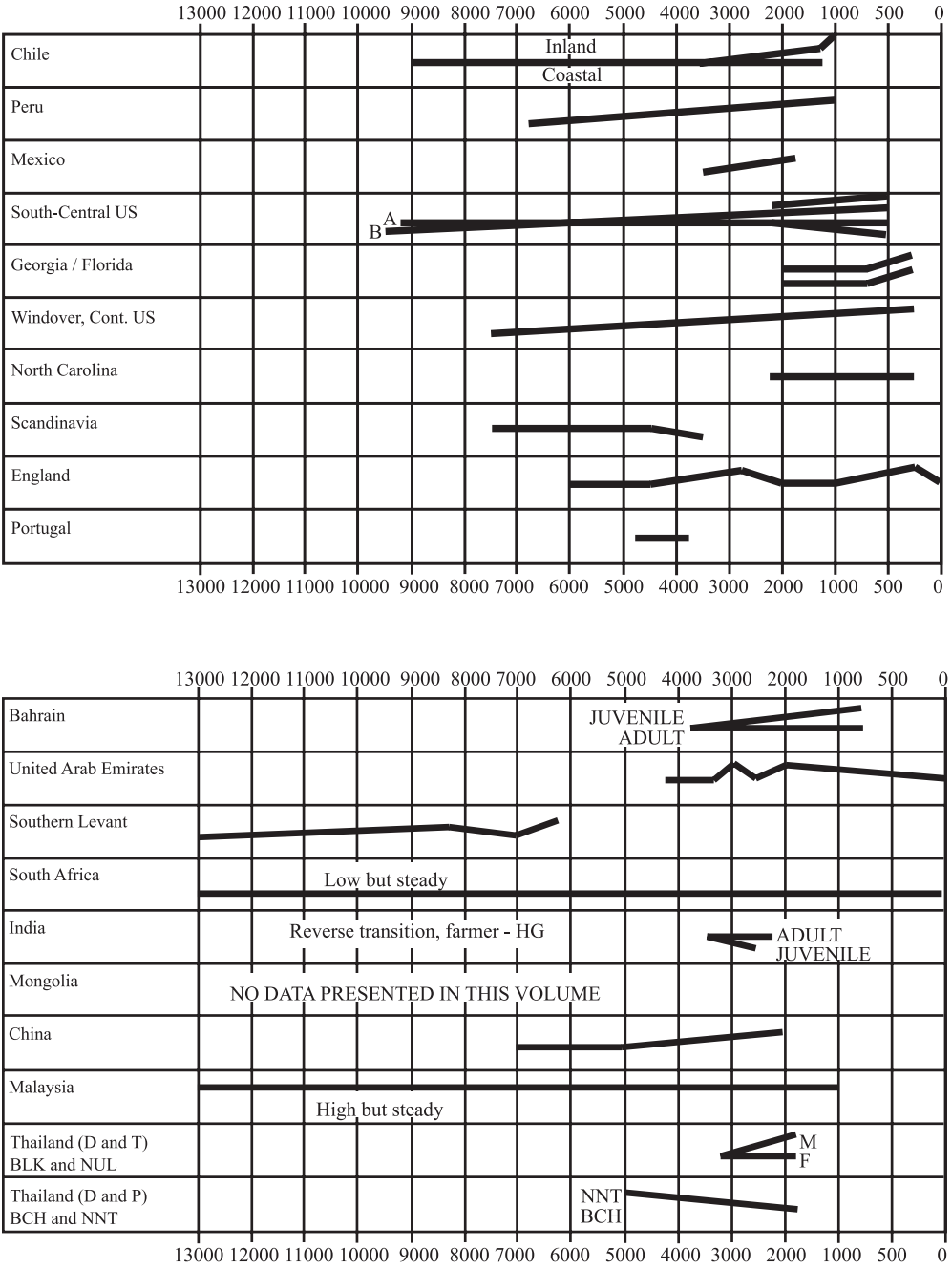

Figure 22.1. Comparison of temporal trends in the frequency of linear enamel hypoplasia in all regions discussed.

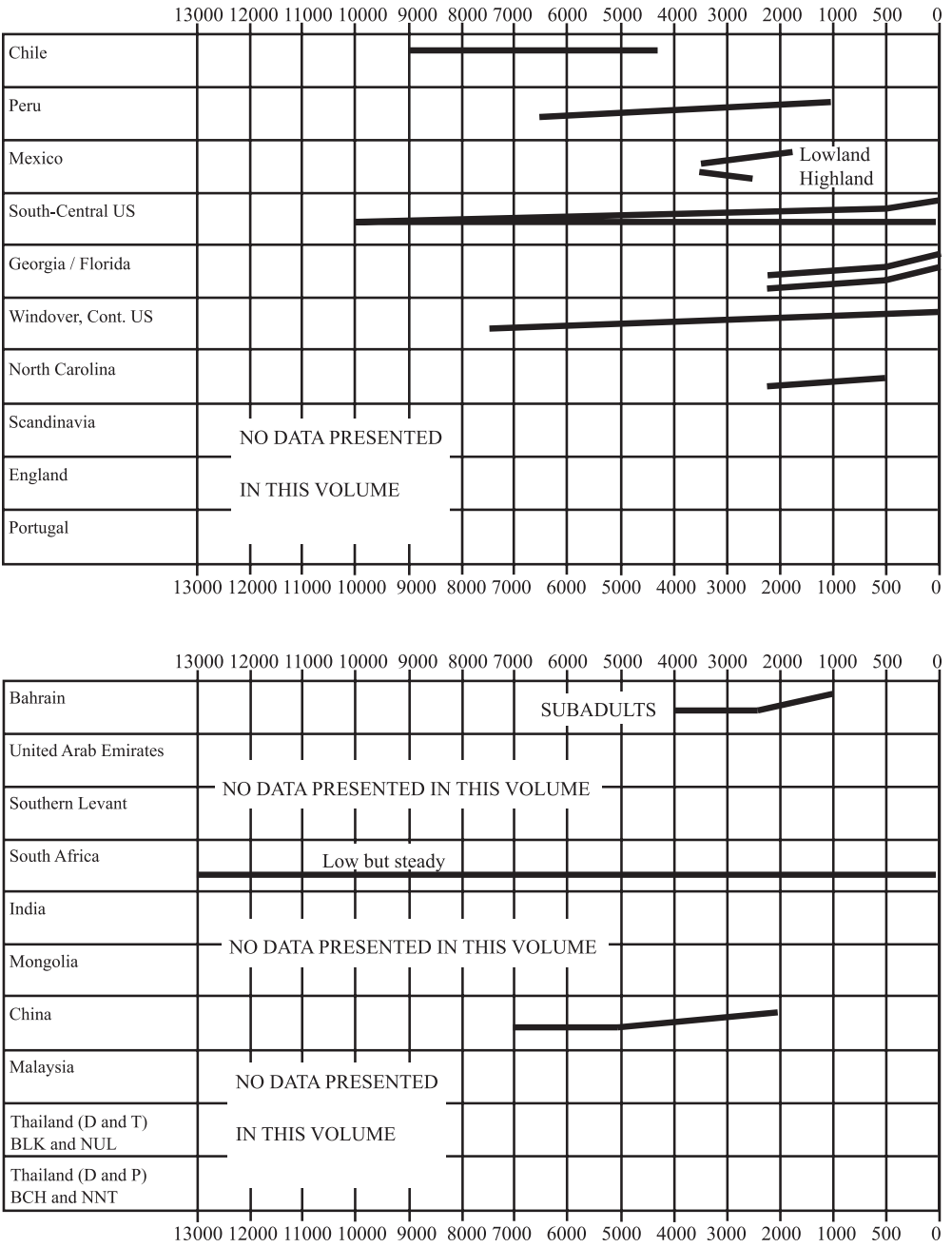

Figure 22.2. Comparison of temporal trends in frequency of porotic hyperostosis in all regions discussed.

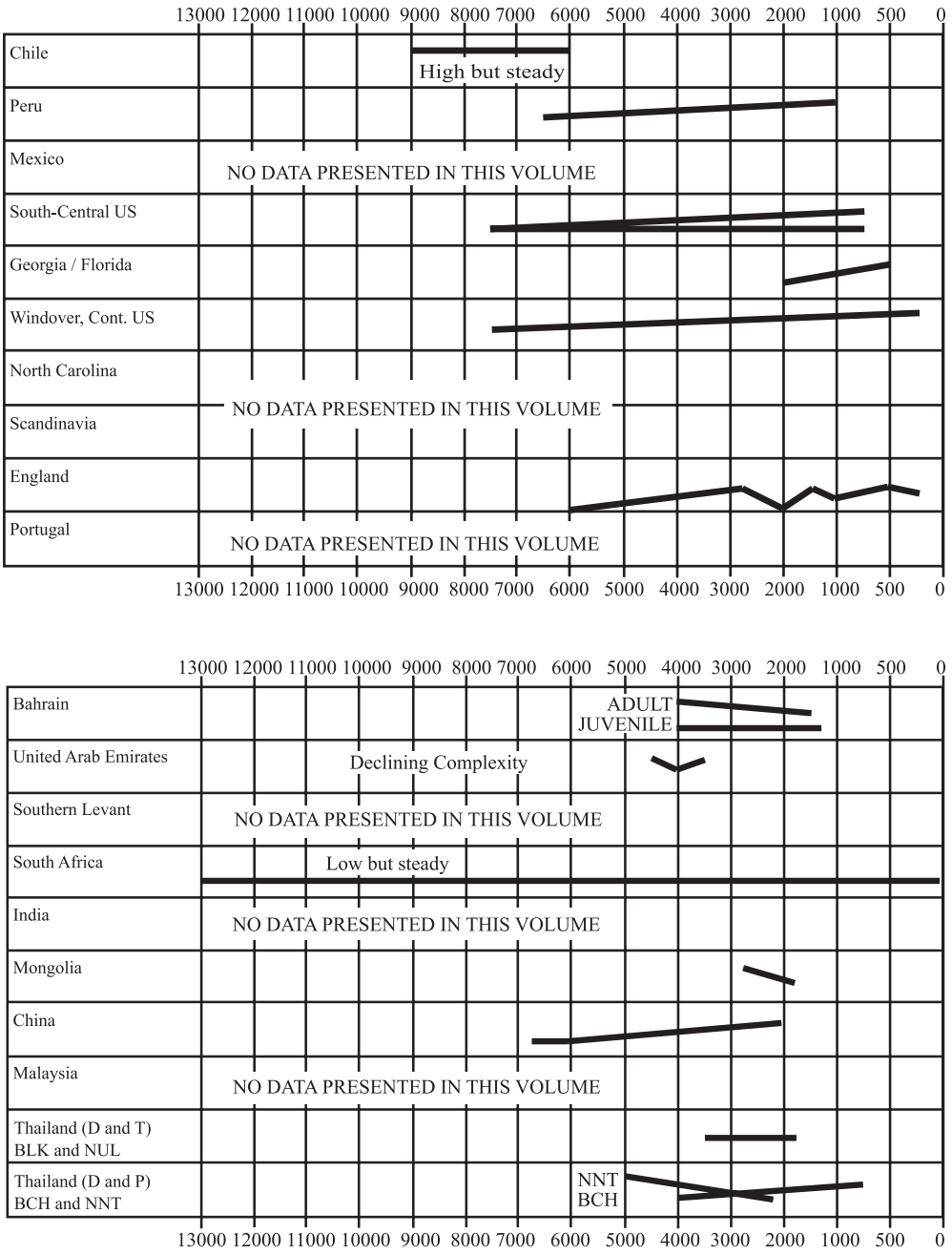

Figure 22.3. Comparison of temporal trends in frequency of cribra orbitalia in all regions discussed.

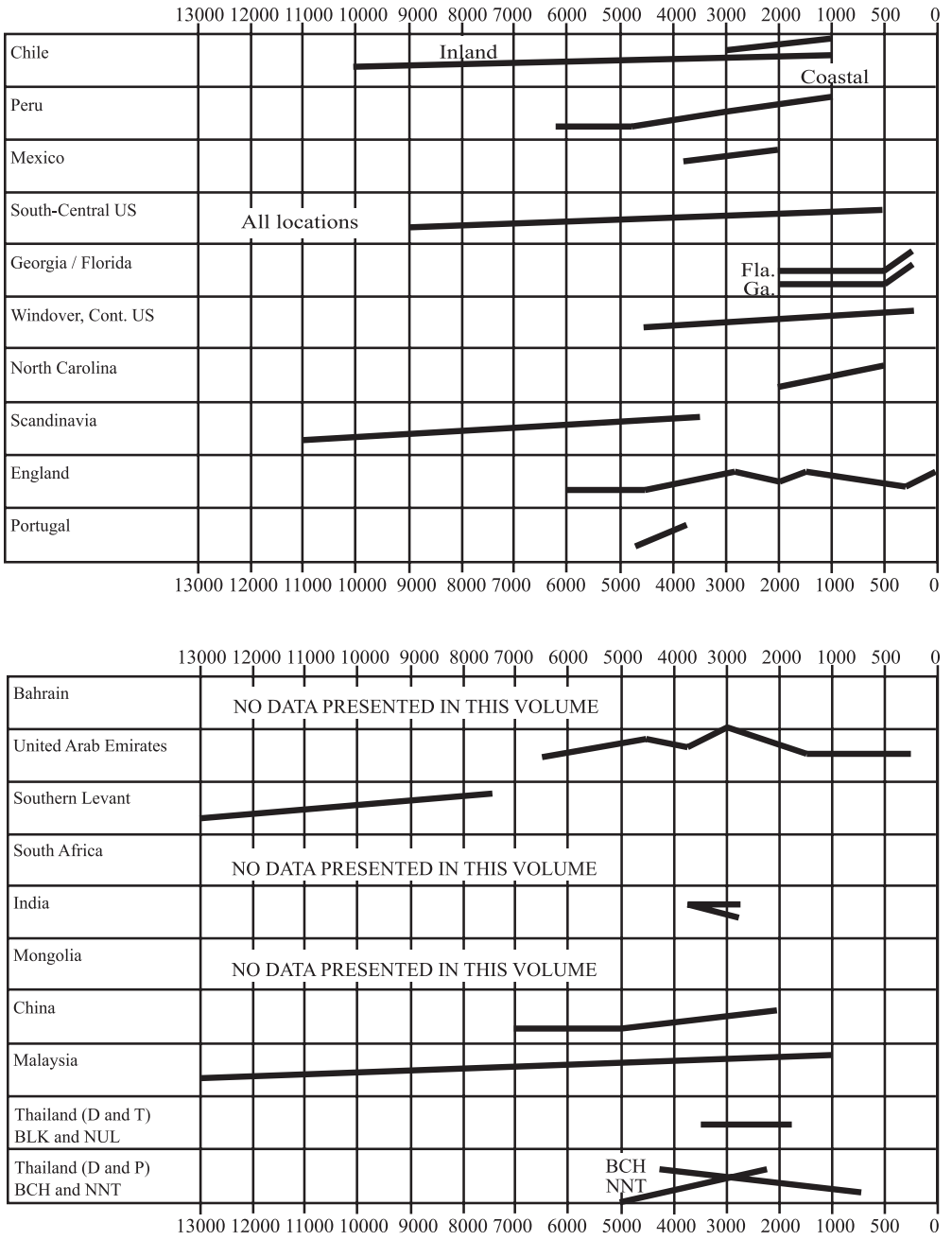

Figure 22.4. Comparison of temporal trends in frequency of caries in all regions discussed.

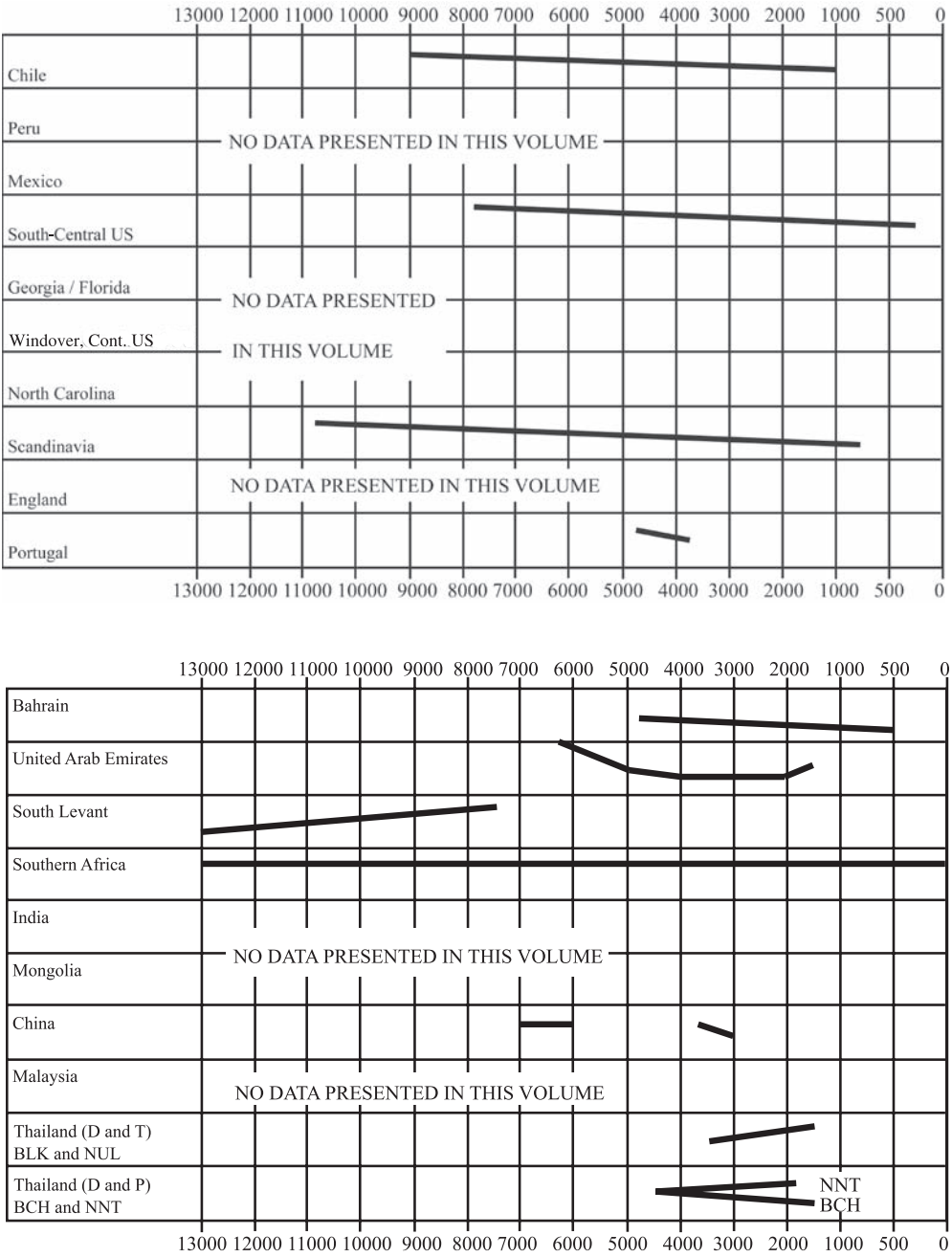

Figure 22.5. Comparison of temporal trends in dental attrition in all regions discussed.

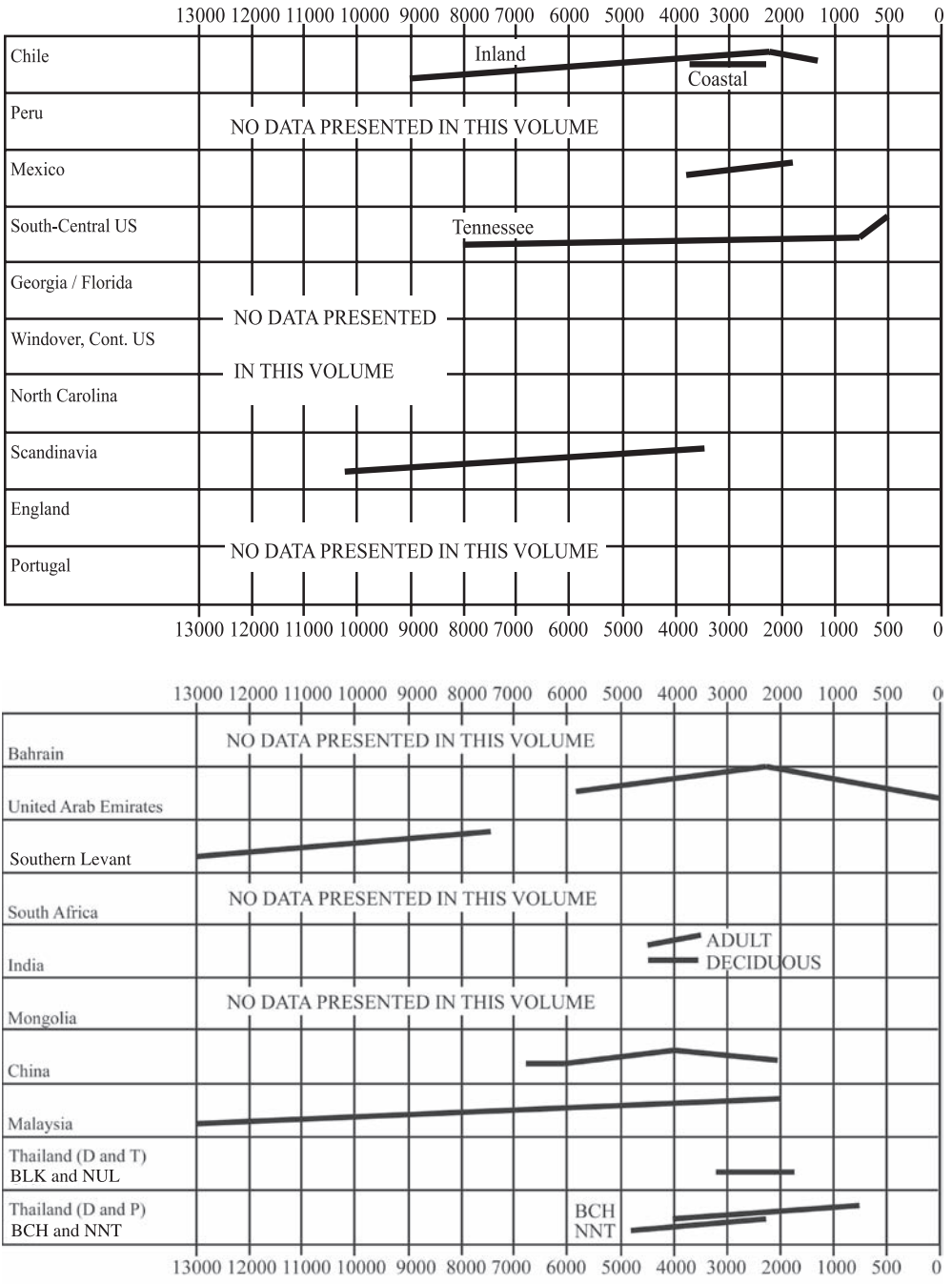

Figure 22.6. Comparison of temporal trends in frequency of antemortem tooth loss in all regions discussed.

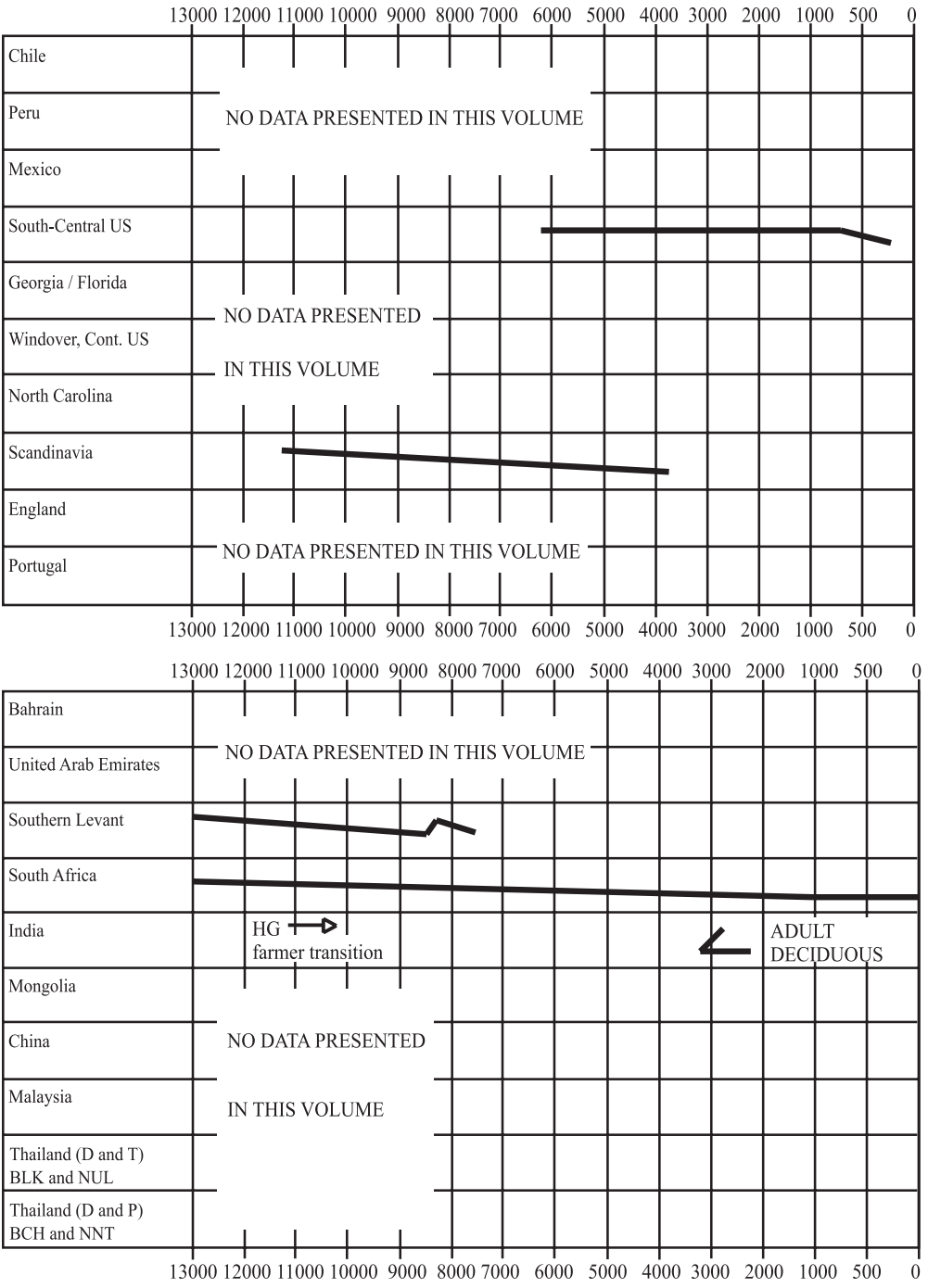

Figure 22.7. Comparison of temporal trends in tooth size in all regions discussed.

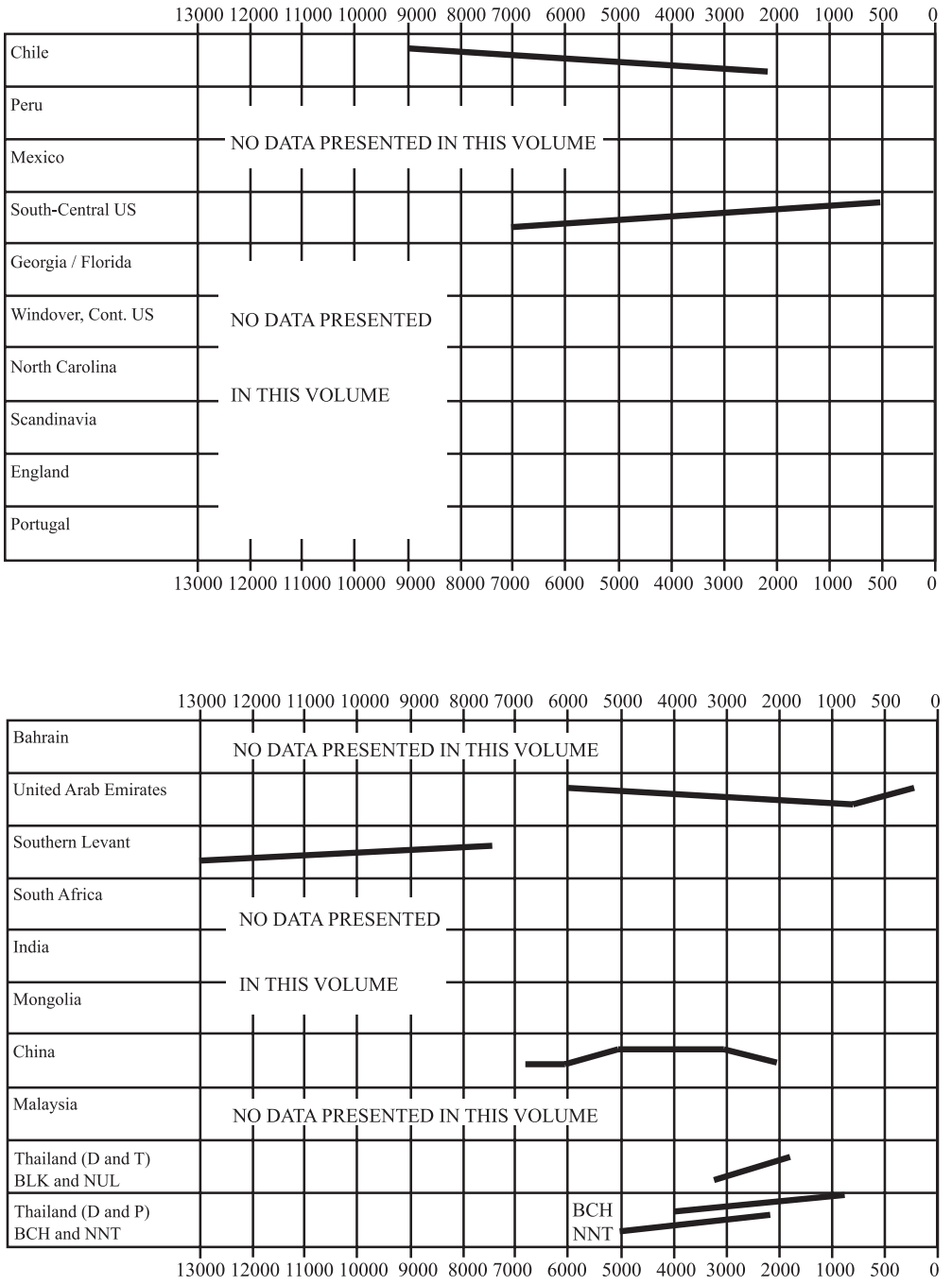

Figure 22.8. Comparison of temporal trends in the frequency of dental abscesses in all regions discussed.

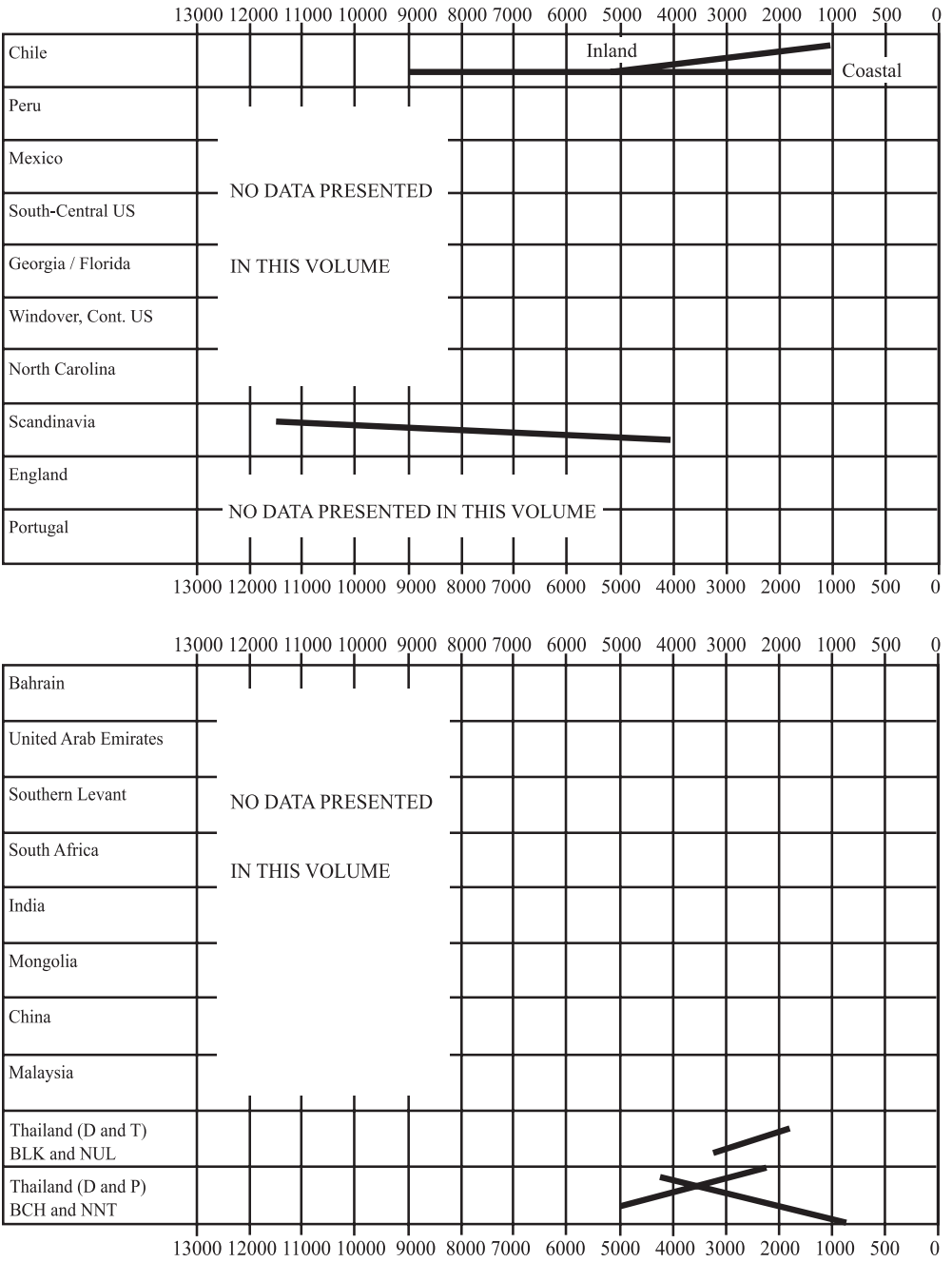

Figure 22.9. Comparison of temporal trends in frequency of dental alveolar resorption in all regions discussed.

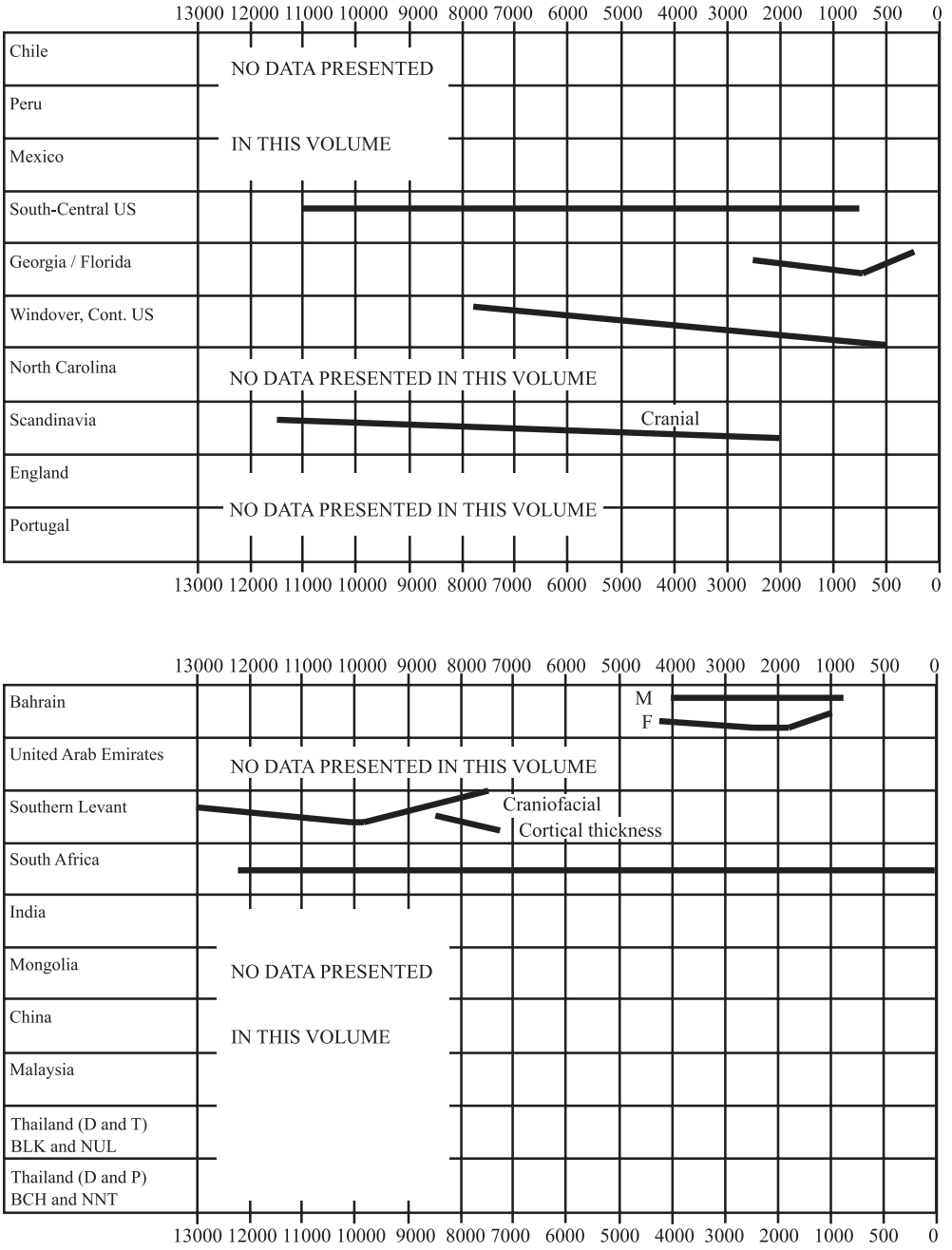

Figure 22.10. Comparison of temporal trends in robusticity in all regions discussed.

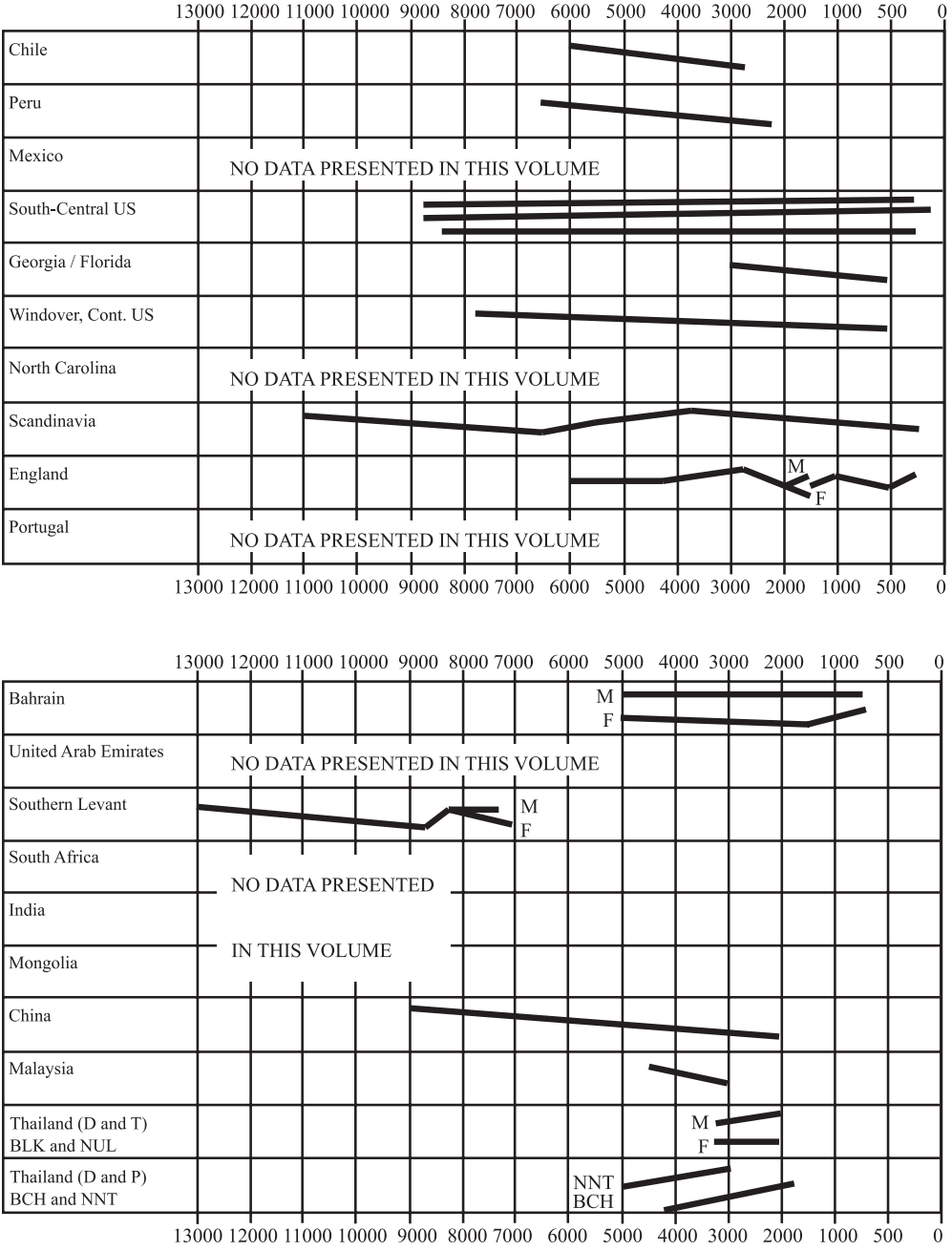

Figure 22.11. Comparison of temporal trends in stature in all regions discussed.

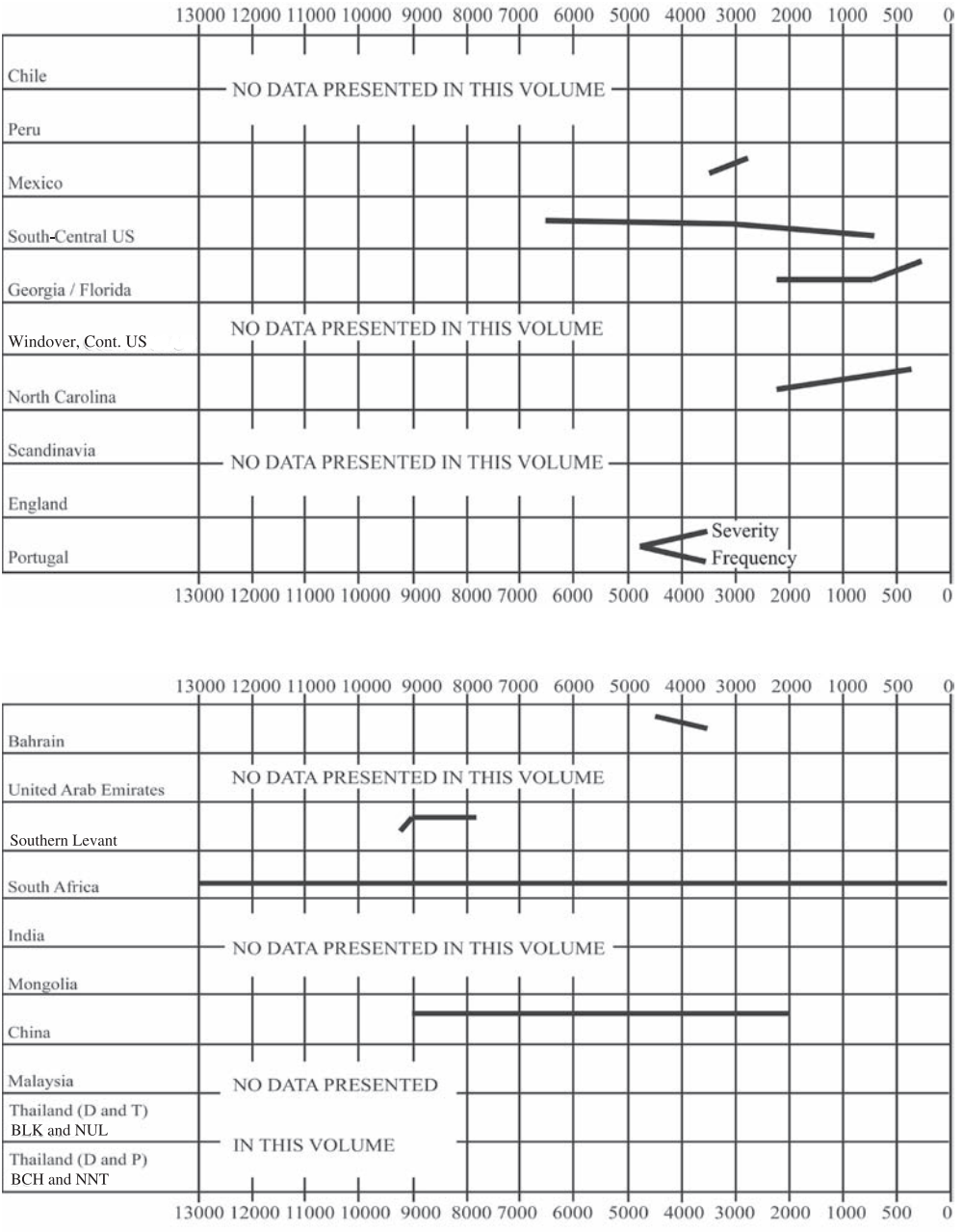
13000 12000 11000 10000 9000 8000 7000 6000 5000 4000 3000 2000 1000 500 0
Chile
NO DATA PRESENTED IN THIS VOLUME
Peru
Mexico
South-Central US
Georgia / Florida
NO DATA PRESENTED IN THIS VOLUME
Windover, Cont. US
North Carolina
Scandinavia
NO DATA PRESENTED IN THIS VOLUME
England
Portugal
Severity
Frequency
13000 12000 11000 10000 9000 8000 7000 6000 5000 4000 3000 2000 1000 500 0
13000 12000 11000 10000 9000 8000 7000 6000 5000 4000 3000 2000 1000 500 0
Bahrain
NO DATA PRESENTED IN THIS VOLUME
United Arab Emirates
Southern Levant
South Africa
India
NO DATA PRESENTED IN THIS VOLUME
Mongolia
China
Malaysia
NO DATA PRESENTED
Thailand (D and T)
BLK and NUL
IN THIS VOLUME
Thailand (D and P)
BCH and NNT
13000 12000 11000 10000 9000 8000 7000 6000 5000 4000 3000 2000 1000 500 0

Figure 22.12. Comparison of temporal trends in osteoarthritis in all regions discussed.

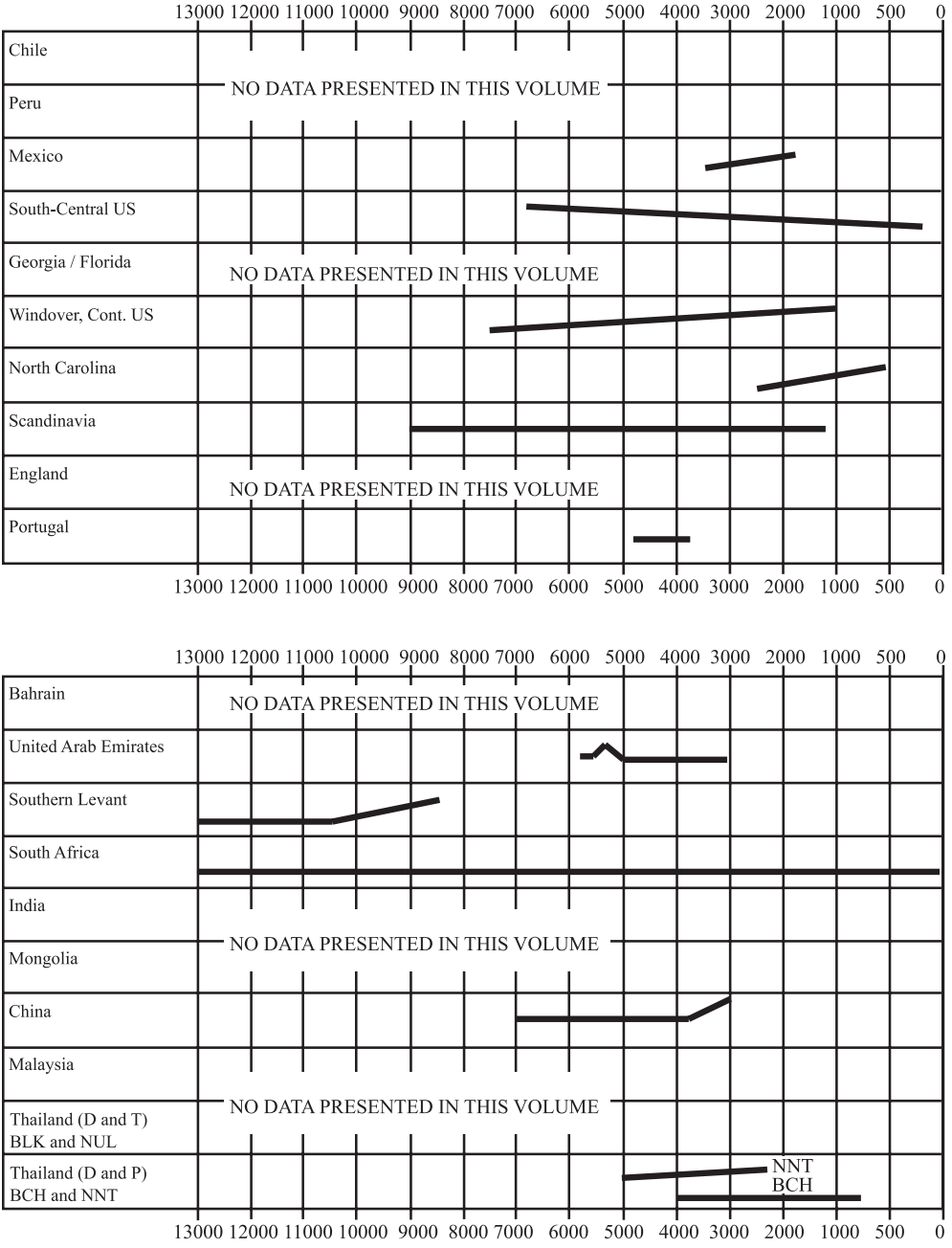

Figure 22.13. Comparison of temporal trends in frequency of trauma in all regions discussed.

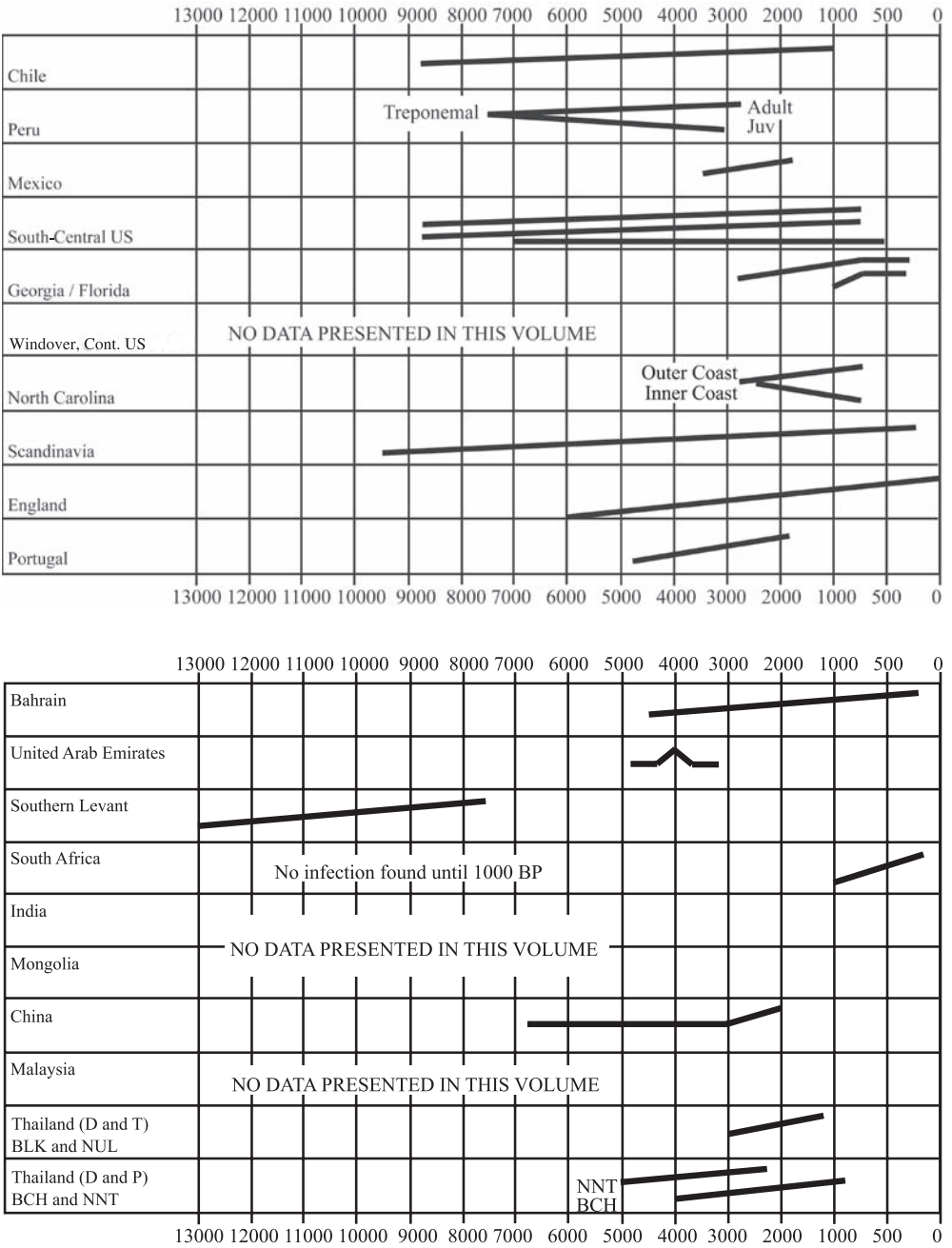

Figure 22.14. Comparison of temporal trends in frequency of infection/periosteal reactions in all regions discussed.

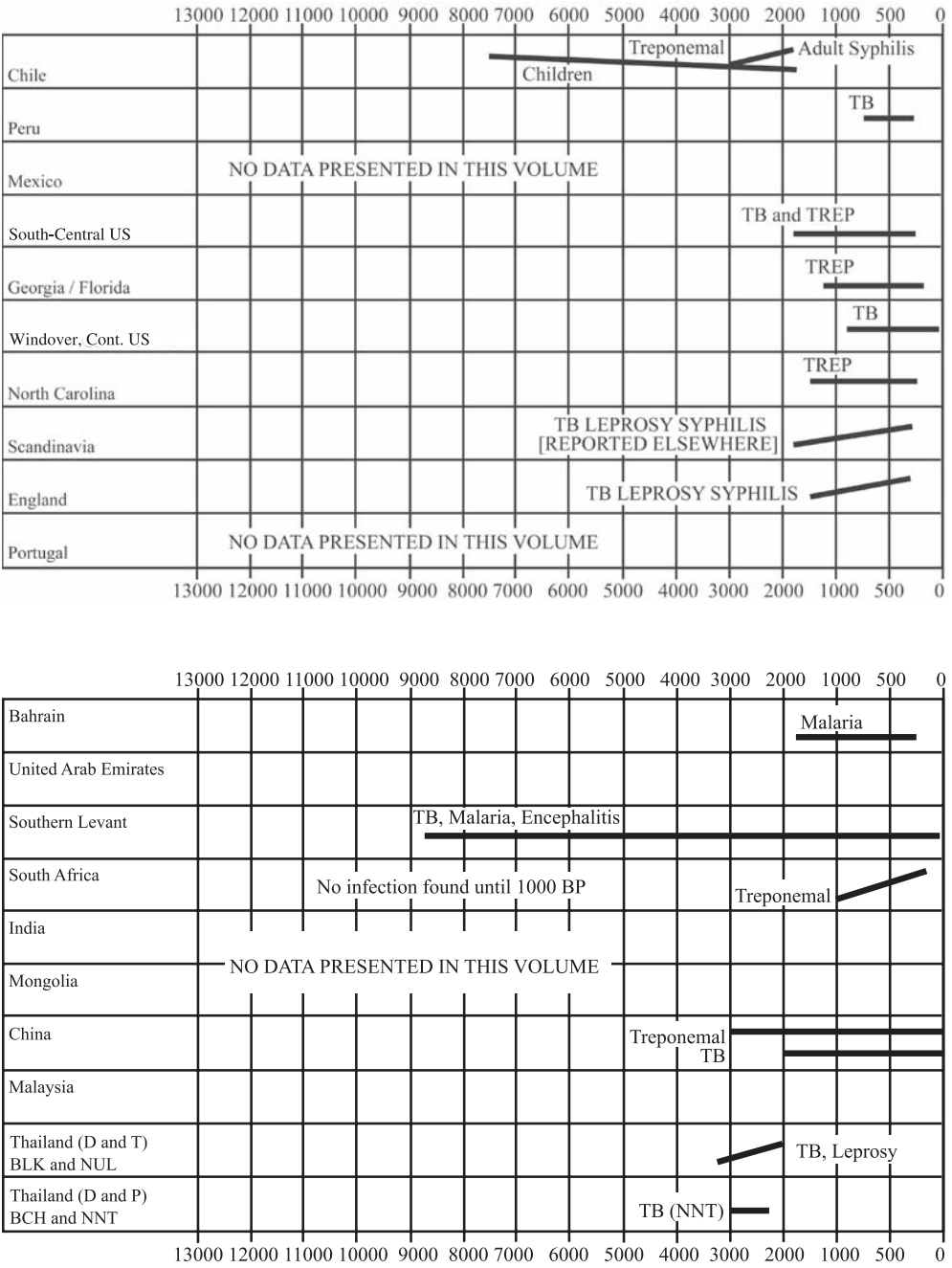

Figure 22.15. First appearance of specific diseases in all regions discussed.

Discussions at the Symposium

In discussions, two types of pathology (porotic hyperostosis and periostitis) were given a broader range of possible interpretation than had previously been recognized. Discussion of porotic hyperostosis focused on the problem of distinguishing iron-deficiency anemia and scurvy. Cook pointed out that periostitis has been too narrowly defined as a nonspecific infection, when in fact a range of noninfectious etiologies may also produce the condition. In both cases, differential diagnoses requires understanding other concomitant health indicators and/or environmental conditions. We (the editors) believe, however, that there is a strong argument to suggest that periostitis does, in fact, most often represent infection. Its frequency commonly corresponds with sedentism and group size as expected of an infection, whereas the pattern is harder to explain if other etiologies are assumed.

Discussion addressed a surprising peak in mortality and morbidity among older children, generally 5–10 years old (reported in several chapters), at ages that should be relatively free of morbidity and mortality. Age-correlated stress indicators in adult bones also display surprising peaks in later childhood, possibly reflecting culturally defined independence of older children and possibly reflecting culturally defined gender discrimination. Because children cannot be sexed, high female mortality in this age range would appear as an increase in mortality in later childhood.

Differential health and mortality by age and sex mentioned in several papers were also discussed. Some demonstrate significant disparity between the sexes in terms of overall health and mortality, usually to the detriment of females. In some cases, cultural discrimination against women's health is clearly indicated; in others, the mix of discrimination and differences in physiology and natural life experiences are difficult to tease apart.

The unusual pattern of mixed or improving health in Southeast Asia was also reviewed, with the explanation focusing on the fact that rice is a healthier domesticate, more easily stored, and less cariogenic than other staple cereals (although the distinction between dry rice agriculture and wet rice agriculture, with its higher parasite load, generally was not made). Few data were provided on the impact of irrigation. Even in this portion of the globe, infection commonly increased through time.

The meaning of declining stature and tooth size in earlier (although not always later) prehistory was discussed, with researchers noting that there are alternatives to the assumption (discussed in the introduction) that both reflect declining health and nutrition. Stature decline might reflect the fact that selection for large size relaxed when it was no longer needed for hunting large prey. The decline might reflect selection of smaller body sizes as adjust-

ments to a new diet, and it might even reflect declining mortality. Wood and colleagues (1992) have suggested that high mortality could tend to eliminate individuals whose health was compromised (hence likely to develop short stature) such that poor community health might actually increase average stature. Conversely, relaxed selection against small, slow-growing individuals (that is, those in better health) could result in decreased average stature. But there is little evidence for this in modern populations (see Appendix).

Tooth size may have declined with relaxed selection for size or with positive selection for reduced complexity of surfaces, reducing the risk of caries. (Caries can actually be major venues for introducing infection, making them a factor in differential mortality and natural selection.). However, Smith pointed out that declining tooth size in prehistory often preceded reduction in the complexity of occlusal surfaces. Moreover, increasing rates of caries clearly became a problem relatively late in archaeological time, after the adoption of farming, when (generally speaking) smaller and simpler teeth had already appeared. We also discussed the hypothesis (suggested by many other scholars) that declining tooth size might be linked to a softer diet and declining jaw size. But teeth and jaws are under control of different genetic systems, and the two often change independently (as indicated by modern tooth crowding).

The editors believe that stature and tooth size (in the range under consideration) are plastic, not genetic, variables. The most likely explanation of decline in the size of either is probably declining nutrition, particularly declining maternal nutrition, during fetal and early childhood growth. The size of both stature and teeth has often changed too fast in prehistory to reflect genetic evolution, and both have increased very rapidly in many places in the last century with improvements in health and nutrition. (See discussion and examples in the introduction and appendix.) In this volume, several authors (Lukacs, Bennike and Alexandersen, and Smith and Horwitz) apply the nutritional hypothesis to rapid changes in tooth size in India, Scandinavia, and the Southern Levant, respectively. (For a modern example of very rapid tooth size change [one generation] in response to health, see Harris et al. 2001.)

Conclusions

Ups and downs in health occur in different economic phases in different sequences, and various health indicators often do not display similar trends even in the same region. Some sequences suggest steadily declining health and/or the relatively good health of people in small-scale societies, often based on hunting and gathering. Most display a preponderance of downward trends. Some describe relatively balanced improvements and declines in health, and some in Southeast Asia describe mixed trends with at least partial improve-

ment in health over time. Regional histories are idiosyncratic, reflecting variations in geography, politics, culture, population size and nucleation, domestication, population movements, and trade. These variables occur in different combination in different regions, and patterns do not always correlate with naïve expectations of time sequence. For example, Lukacs describes the health results of a temporal transition from farming to hunting and gathering; in some sequences, such as in the United Arab Emirates, degrees of cultural complexity do not necessarily increase through time. Some sequences, such as those in Bahrain and India, are heavily affected by climate fluctuations as well as culture change. These regional and historical variations underline the fact that nothing more than broad general parallels should be expected among the sequences.

Overall, evidence of health decline through time is far more common than evidence of stability or improvement. The graphs suggest that LEH most commonly increases except in Southeast Asia. PH most commonly increases, but trends in CO are mixed. Rates of caries (and possibly related infection) commonly increase, as do rates of AMTL and abscesses, but dental attrition commonly declines. In two cases reported, the Southern Levant and Scandinavia, tooth size appears to decline with the adoption of agriculture (a widespread trend summarized in our introductory chapter). Tooth size also declines among historic South African foragers and among populations from the late prehistoric south-central United States. When farmers reverted to hunting and gathering in India, tooth size increased. Although data are mixed, stature more often declines than increases, except in Southeast Asia. Osteoarthritis generally increases; trauma data are quite mixed; rates of infection almost universally increase; and specific identifiable disease such as TB, treponemal infections, and leprosy (as well as possible malaria and encephalitis) always occur near the end of the reported sequences.

Work in this volume alone or in combination with other recent studies since 1984 (summarized in our introduction) clearly suggests that health and nutrition more often declined than advanced amid economic and political "progress." The presumption that health commonly declined through prehistory remains one of the more robust broad conclusions about prehistory.

Appendix

Despite recent criticisms, straightforward interpretations of *relative* pathology frequencies in two or more past populations can generally be made from their cemeteries without concern for paradoxical interpretations.

Ortner (1992, 1998) notes that visible pathology forms slowly in bone. As a result, a skeleton without visible pathology might represent an individual who never suffered a particular disease or one who suffered so severely that (s)he died before the pathology affected the skeleton. Individuals displaying pathology might paradoxically be healthier and longer-lived than those who display no pathology. Visible pathology in cemeteries might increase not because more people got sick but because more people lived long enough for pathology to register in their skeletons.

The "osteological paradox" (Wood et al. 1992; see also Milner et al. 2000) argues that cemeteries are not necessarily fair samples of the living populations from which they are derived, because chance, differential frailty, and selective mortality may all affect the cemetery samples, so frequencies of pathology in cemeteries have no predictable relationship to the pathology of populations they represent. If this were true, no conclusions about pathology in a prehistoric population could be drawn from its cemetery.

Several arguments can be offered in rebuttal of both arguments, at least where comparisons between populations are attempted (see also Cohen 1997).

First, Goodman (1993) and Wright and Yoder (2003) suggest that using multiple independent lines of evidence may circumvent the problems of the so-called paradox. Good candidates are ethnographic observation and uniformitarianism. Cohen (1989) provides summary paleopathological data (as directly interpreted), modern epidemiology, and uniformitarian logic used to reconstruct ancient disease patterns. The three lines of evidence converge on the same conclusions, strengthening conclusions from the direct interpretation of skeletons. Skeletal pathology frequencies largely accord with expectations from other lines of analysis, suggesting that neither Ortner's argument nor the paradox argument applies.

Second, the paradox argument overstates the importance of differential frailty and selective mortality on cemetery populations, at least with regard to the relatively chronic conditions that appear in skeletons and that may contribute to the probability of death without themselves being lethal.

Those with a specific pathology in any cemetery come from one of two groups: individuals whose deaths are hastened ("selected") by their chronic condition; and those whose deaths are random relative to a particular pathology. For example, if individuals with or without pathology are killed by bad luck or "outside events" with no regard to differential frailty (for example, a cave roof collapses), those dead will be a random sample of the living and will, on average, reflect the population's rates of pathology accurately. But those dying "selectively" will also reflect the frequency of pathology among the living because the selected group reflects the strength of selection multiplied by the original frequency of the pathology in the population. Despite selective mortality, the original pathology frequency in the living population exerts a powerful influence on its frequency in the cemetery (compare Wright and Chew 1998).

If the strength of selection changes dramatically from population to population, this argument might not hold. Epidemics of acute disease that kill rapidly without scarring the skeleton are prone to "paradoxical" interpretation. No skeletal pathology may reflect rapid death. But these diseases have widespread effects only relatively late in prehistory. Therefore, the skeletal invisibility of epidemics should result in underestimation—rather than negation—of the pattern of declining health commonly observed in history.

We can interpret stress markers of childhood events, such as enamel hypoplasia, in the same way. High frequencies of hypoplasia could indicate a high frequency of stress episodes. Hypoplasia can also be considered an indication of good health, as implied by Ortner (1992, 1998).

Adults who show no hypoplasia cannot have died before the stress marker could form: that adult must not have experienced the stress. Therefore, when adults are compared, few hypoplasias mean few stresses, whereas more hypoplasias mean more stresses. Ortner would argue that absence of hypoplasia among adults, however, reflects high childhood mortality instead of health. But it does not. The assumption that more LEH means more health problems, not survival, is almost certainly correct. Which is more likely—that children died of stresses that adults did not even record in teeth, or that they died of stresses that others survived but recorded? Surely the latter is more probable. More hypoplasia in adults must mean higher, not lower, childhood mortality.

Third, if cemetery populations are misleading samples, where are the paradoxical results? There ought to be many results that make no sense vis-à-vis the results of theoretical expectations. But paleopathological data repeatedly match the expectations of data from ethnographic studies and uniformitarian assumptions. Skeletal signs of anemia and infection (including tuberculosis, syphilis, and leprosy) increase when and where we would expect.

If Ortner were correct, we should find higher rates of visible pathology in upper-class populations, both living and prehistoric. If the paradox argument were correct, we might expect average statures to be smaller in upper-class populations. But neither is the case. Taller stature and relatively low rates of visible pathology are routinely found in upper classes (Tristan et al. 1982; Betsinger 2002; Danforth 1999 and references cited in Danforth et al. this volume; Goodman 1998; Goodman and Martin 2002; Goodman et al. 1991, 1992; Harris et al. 2001; Hatch and Willey 1974 and references cited therein; Lukacs and Joshi 1992; Powell 1988, 1991; Rathbun and Scurry 1991; Zhou and Corrucini 1994).

For these reasons, we argue that broad patterns in quantitative paleopathology, at least when comparisons between populations are intended, *do* fairly represent the relative frequency of pathology in the populations from which the cemeteries were created.

Bibliography

Acheson, R. M. 1960. Effects of Nutrition and Disease on Human Growth. In *Human Growth,* ed. J. M. Tanner, 73–92. Sussex, U.K.: Pergamon Press.

Acsadi, G., and J. Nemescari. 1970. *History of Human Life Span and Mortality.* Budapest: Akadémiai Kiade.

Adi Haji Taha. 1985. The Re-excavation of the Rockshelter of Gua Cha, Ulu Kelantan, West Malaysia. *Federal Museums Journal* 30: 1–130.

Agarwal, S. C., and M. D. Grynpas. 1996. Bone Quantity and Quality in Past Populations. *Anatomical Record* 246: 423–32.

Agelarkis, A., and D. B. Waddel. 1994. Analysis of Non-specific Indicators of Stress in Sub Adult Skeletons during the Agricultural Transition from Southwestern Asia. *Homo* 45 supplement.

Ahlström, T. 1994. Landmark Morphometrics and Osteology. Thesis. Stockholm: Osteological Research Laboratory.

———. 2003. Caries or Pottery? On the Reduction in Tooth Size in the Neolithic Age. In *A Tooth for a Tooth,* ed. E. Iregren and L. Larsson, 46–64. Reportserie 87. Lund: University of Lund.

Aiello, L. C., and P. Wheeler. 1995. The Expensive Tissue Hypothesis. *Current Anthropology* 36: 199–221.

Al-Abbasi El-Din, S. A., and I. Sarie. 1997. Prevalence of Dental Enamel Hypoplasia in the Neolithic Site of Wadi Shu'eib in Jordan. *Dental Anthropology* 11: 1–4.

———. 1998. Neolithic Collapse in the Levant Viewed from Dental Enamel Hypoplasia. *American Journal of Physical Anthropology* supplement 26: 62–63.

Albrethsen, S. E., V. Alexandersen, J. B. Jørgensen, and E. B. Petersen. 1976. De Levede og Døde for 7000 år Siden. *Nationalmuseets Arbejdsmark* 5–24.

Alexandersen, V. 1988. Description of the Human Dentitions from the Late Mesolithic Grave-Fields at Skateholm, Southern Sweden. In *The Skateholm Project,* vol. 1, *Man and Environment,* ed. L. Larsson, 106–63. Stockholm: Almquist and Wiksell Int.

———. 1989. Tandforholdene i enkeltgravstid/stridsøksetid. In *Stridsyksekultur i Sydskandinavien,* ed. by Larsson, 169–80. Institute of Archaeology Reportserie 36. Lund.

———. 2003. Dental Variation and Change through Time in Nordic Population. In *A Tooth for a Tooth,* ed. E. Iregren and L. Larsson, 9–36. Reportserie 87. Lund: University of Lund.

Allison, M., E. Gerszten, J. Munizaga, C. Santoro, and D. Mendoza. 1981. Tuberculosis in Pre-Columbian Andean Populations. In *Prehistoric Tuberculosis in the Americas,* ed. J. E. Buikstra, 69–81. Evanston, Ill.: Northwestern University Archeological Program.

Allison, M., D. Mendoza, and M. Pezzia. 1973. Documentation of a Case of Tuberculosis in Pre-Columbian America. *American Review of Respiratory Diseases* 107: 985–91.

Al-Tikriti, W. Y. 1989. Umm an-Nar Culture in the Northern Emirates: Third Millennium BC Tombs at Ajman. *Archaeology in the United Arab Emirates* 9: 89–98.

Ambrose, S. H. 1990. Preparation and Characterization of Bone and Tooth Collagen for Stable Carbon and Nitrogen Isotope Analysis. *Journal of Archaeological Science* 17: 293–317.

———. 1993. Isotopic Analysis of Paleodiets: Methodological and Interpretive Considerations. In *Investigations of Ancient Human Tissue: Chemical Analyses in Anthropology,* ed. M. K. Sandford, 59–103. New York: Gordon and Breach.

Ambrose, S. H., J. Buikstra, and H. W. Krueger. 2003. Status and Gender Difference in Diet at Mound 72, Cahokia, Revealed by Isotopic Analysis of Bone. *Journal of Anthropological Archaeology* 22: 217–26.

Ambrose, S. H., and L. Norr. 1993. Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate. In *Prehistoric Human Bone: Archaeology at the Molecular Level,* ed. J. B. Lambert and G. Grupe, 1–37. Berlin: Springer-Verlag.

Ammermann, A. J., and L. L. Cavalli-Sforza. 1984. *The Neolithic Transition and the Genetics of Populations in Europe.* Princeton, N.J.: Princeton University Press.

An, Zhimin. 1959. Discussion of Neolithic Culture in the Yellow River Valley. *Kaogu* 10: 559–65.

———. 1984. Early Neolithic Culture in North China. *Kaogu* 10: 936–44. Translated by Elaine Wong and Bryan Gordon.

Anderson, D. D. 1997. Cave Archaeology in Southeast Asia. *Geoarchaeology* 12: 607–38.

Anderson, D. G., and M. K. Faught. 2000. Paleoindian Artefact Distributions: Evidence and Implications. *Antiquity* 74: 507–13.

Anonymous. 1995. *The Europa World Year Book,* vol. 2. London: Europa Publication.

———. 2003. <http://www.weathersa.co.za>. South African Weather Service.

Araújo, A. C. 1999. A Indústria Lítica Do Concheiro De Poças De S.Bento Vale Do Sado No Seu Contexto Regional. *O Arqueólogo Português* 4, nos. 13–15: 87–159.

Arensburg, B., and I. Hershkovitz. 1988. Nahal Hemar Cave, Neolithic Human Remains. *Atiqot* 18: 50–58.

Arensburg, B., P. Smith, and R. Yakar. 1978. The Human Remains from Abou-Ghosh. In *Abou Ghosh et Beisamoun deux gisements du VIIe millenaire avant l'ere chretienne en Israel,* ed. M. Lechevallier, 107–20. Memoires et Travaux du Centre de Recherches Prehistoriques Francais de Jerusalem 2. Paris: Association Paléorient.

Armelagos, G. J., A. H. Goodman, and K. H. Jacobs. 1991. The Origins of Agriculture: Population Growth during a Period of Declining Health. *Population and Environment* 13: 9–22.

Armelagos, G. J., and D. P. van Gerven. 2003. A Century of Skeletal Biology and Paleopathology: Contrasts, Contradictions, and Conflicts. *American Anthropologist* 105: 53–64.

Arnaud, J. M. 1989. The Mesolithic Communities of the Sado Valley, Portugal, in Their Ecological Setting. In *The Mesolithic in Europe: Papers Presented at the Third International Symposium, Edinburgh, 1985,* ed. C. Bonsall, 614–31. Edinburgh: John Donald.

Arnold, C. J. 1997. *An Archaeology of the Early Anglo-Saxon Kingdoms.* London: Routledge.

Arriaza, B. T. 1994. Tipología de las Momias Chinchorro y Evolución de las Prácticas de Momificación. *Chungara* 26: 11–24. Arica, Chile.

———. 1995. Chinchorro Bioarchaeology: Chronology and Mummy Seriation. *Latin American Antiquity* 6: 35–55.

Arriaza, B. T., A. C. Aufderheide, and I. Muñoz. 1993. Bioarqueología: Análisis Antropológico Físico de la Inhumación de Acha-2. In *Acha-2 y los orígenes del poblamiento humano en Arica,* ed. I. Muñoz, B. T. Arriaza, and A. C. Aufderheide, 47–62. Arica, Chile: Editorial Universidad de Tarapacá.

Arriaza, B. T., W. L. Salo, A. C. Aufderheide, and T. A. Holcomb. 1995. Pre-Columbian Tuberculosis in Northern Chile: Molecular and Skeletal Evidence. *American Journal of Physical Anthropology* 98: 37–45.

Ashkenazi, T. 1956. *The Bedouin: Their Origin, Life and Customs.* Tel Aviv: Reuven Mas. (In Hebrew.)

Astrom, S., and A. von der Decken. 1983. Lysine Deficiency Reduces Transcription Activity and Concentration of Chromatin Proteins Reversibly in Rat Liver. *Acta Physiologica Scandinavia* 117: 519–25.

Aufderheide, A. C., and C. Rodriguez-Martin. 1998. *The Cambridge Encyclopedia of Human Paleopathology.* Cambridge, U.K.: Cambridge University Press.

Badarch, N. 1971. *Mongol ornii uur amisgal.* (The Climate of Mongolia.) Ulaanbaatar: Mongolian Academcy of Sciences. (In Mongolian.)

Bahn, P. 2003. *Written in Bones: How Human Remains Unlock the Secrets of the Dead.* Toronto: Firefly Books.

Bailey, R. C., G. Head, M. Jenike, B. Owen, R. Rechtman, and E. Zechenter. 1989. Hunting and Gathering in Tropical Rain Forest: Is It Possible? *American Anthropologist* 91: 59–82.

Baker, B., and G. J. Armelagos. 1988. Origin and Antiquity of Syphilis: A Paleopathological Diagnosis and Interpretation. *Current Anthropology* 295: 703–37.

Barbujani, G., A. Pilastro, S. D. Domenico, C. Renfrew. 1995. Genetic Variation in North Africa and Eurasia: Neolithic Demic Diffusion vs. Paleolithic Colonisation. *American Journal of Physical Anthropology* 95: 137–54.

Barker, D. E. 1997. Sharm: A Typological and Scientific Analysis of Wadi Suq and Iron Age Period Ceramics from Fujairah, United Arab Emirates. B.A. honors thesis, University of Sydney.

Barker, G., H. Barton, P. Beavitt, M. Bird, P. Daly, C. Doherty, D. Gilbertson, and others. 2002. Prehistoric Foragers and Farmers in Southeast Asia: Renewed Investigations at Niah Cave, Sarawak. *Proceedings of the Prehistoric Society* 68: 147–64.

Barker, G., H. Barton, M. Bird, P. Daly, I. Datan, A. Dykes, L. Farr, and others. 2007. The "Human Revolution" in Lowland Tropical Southeast Asia: The Antiquity and Behavior of Anatomically Modern Humans at Niah Cave (Sarawak, Borneo). *Journal of Human Evolution* 52: 243–61.

Bar-Yosef, O. 1998. The Natufian Culture in the Levant: Threshold to the Origins of Agriculture. *Evolutionary Anthropology* 6: 159–77.

Bar-Yosef, O., and A. Belfer-Cohen. 1992. From Foraging to Farming in the Mediterranean Levant. In *Transitions to Agriculture in Prehistory,* ed. A. B. Gebauer and T. D. Price, 21–48. Monographs in World Archaeology 4. Madison, Wis.: Prehistory Press.

———. 1999. Facing Environmental Crisis: Societal and Cultural Changes at the Tran-

sition from the Younger Dryas to the Holocene in the Levant. In *The Dawn of Farming in the Near East,* ed. R. T. J. Capers and S. Botema, 55–66. Berlin: Ex Oriente.

Bar-Yosef, O., and R. H. Meadow. 1995. The Origins of Agriculture in the Near East. In *Last Hunters, First Farmers,* ed. T. D. Price and A. B. Gebauer, 39–94. Houston, Tex.: School of American Research.

Bass, W. 1981. *Human Osteology.* Columbia: Missouri Archaeological Society.

———. 1995. *Human Osteology.* Columbia: Missouri Archaeological Society.

Bates, J. H. 1982. Tuberculosis Susceptibility and Resistance. *American Review of Respiratory Disease* 125: 20–24.

Batsuuri, J. 1986. *The Hereditary Polymorphism and Genegeography of Mongolia's Population.* Moscow: Russian Academy of Sciences.

Bayard, D. T. 1971. *Non Nok Tha: The 1968 Excavation, Procedure, Stratigraphy, and Summary of the Evidence.* University of Otago Studies in Prehistoric Anthropology 4. Dunedin, New Zealand: University of Otago.

———. 1984. Rank and Wealth at Non Nok Tha: The Mortuary Evidence. In *Southeast Asian Archaeology at the XV Pacific Science Congress: The Origins of Agriculture, Metallurgy, and the State, Mainland Southeast Asia,* ed. D. Bayard, 87–122. University of Otago Studies in Prehistoric Anthropology 16. Dunedin, New Zealand: University of Otago.

———. 1996–97. Bones of Contention: The Non Nok Tha Burials and the Chronology and Context of Early Southeast Asian Bronze. In *Ancient Chinese and Southeast Asian Bronze Age Cultures,* ed. F. D. Bulbeck, vol. 2, 889–940. Taipei: SMC.

Beckett S., and N. C. Lovell. 1994. Dental Disease Evidence for Agriculture Intensification in the Nubian C Group. *Journal of Osteoarcheology* 4: 223–40.

Beinert, H. D. 2001. The Pre-Pottery Neolithic B PPNB of Jordan: A First Step towards Proto-urbanism? *Studies in the History and Archaeology of Jordan* 7: 107–19.

Belfer-Cohen, A. 1991. The Natufian in the Levant. *Annual Review of Anthropology* 20: 167–86.

Belfer-Cohen, A., and B. Arensburg. 1997. The Skeletal Remains. In *An Early Neolithic Village in the Jordan Valley,* ed. O. Bar-Yosef and A. Gopher, 201–208. Part 1 of *The Archaeology of Netiv Hagdud.* American School of Prehistoric Research Bulletin 43. Cambridge, Mass.: Peabody Museum.

Belfer-Cohen, A., B. Arensburg, O. Bar-Yosef, and A. Gopher. 1990. Human Remains from Netiv Hagdud—A PPNA Site in the Jordan Valley. *Journal of the Israel Prehistoric Society* 23: 79–85.

Belfer-Cohen, A., and O. Bar-Yosef. 2000. Early Sedentism in the Near East: A Bumpy Ride to Village Life. In *Life in Neolithic Farming Communities: Social Organization, Identity and Differentiation,* ed. I. Kuijt, 19–36. New York: Kluwer Academic.

Belfer-Cohen, A., and N. Goring-Morris. 1996. The Late Epipaleolithic as the Precursor of the Neolithic: The Lithic Evidence. In *Neolithic Chipped Lithic Industries of the Fertile Crescent and Their Contemporaries in Adjacent Regions,* ed. S. K. Kozlowski and H. G. Gebel, 217–25. Berlin: Ex Oriente.

Belfer-Cohen, A., L. A. Schepartz, and B. Arensburg. 1991. New Biological Data for the Natufian Populations in Israel. In *The Natufian Culture in the Levant,* ed. O. Bar-Yosef and F. R. Valla, 411–24. Monographs in International Prehistory, Archaeology Series 1. Ann Arbor, Mich.

Bellwood, P. 1990. From Late Pleistocene to Early Holocene in Sundaland. In *The World at 18,000 BP,* ed. C. S. Gamble and O. Soffer, vol. 2, 255–63. London: Unwin Hyman.

———. 1993. Cultural and Biological Differentiation in Peninsular Malaysia: The Last 10,000 Years. *Asian Perspectives* 32: 37–60.

———. 1997. *Prehistory of the Indo-Malaysian Archipelago,* rev. ed. Honolulu: University of Hawai'i Press.

Bellwood, P., R. Gillespie, G. B. Thompson, J. S. Vogel, I. W. Ardika, and Ipoi-Datan. 1992. New Dates for Prehistoric Asian Rice. *Asian Perspectives* 32: 37–60.

Bellwood, P., and C. Renfrew. 2003. *Examining the Farming/Language Dispersal Hypothesis*. Cambridge, U.K.: McDonald Institute for Archaeological Research

Bender, M. M., D. A. Baerreis, and R. L. Steventon. 1981. Further Light on Carbon Isotopes and Hopewell Agriculture. *American Antiquity* 46: 346–53.

Benfer, R. A., Jr. 1984. Challenges and Rewards of Sedentism: The Preceramic Village of Paloma, Peru. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 531–58. Orlando, Fla.: Academic Press.

———. 1990. The Preceramic Period Site of Paloma, Peru: Bioindications of Improving Adaptation to Sedentism. *Latin American Antiquity* 1: 284–318.

———. 1997. Where Stature Estimated from Regression of Limb Bone Length Is Inappropriate. *American Journal of Physical Anthropology* supplement 24: 74.

Bennike, P. 1985. *Paleopathology of Danish Skeletons: A Comparative Study of Diseases, Injuries and Demography.* Copenhagen: Akademisk Forlag.

———. 1988. Causes of Death in the Early Neolithic Period in Denmark. *Rivista di Anthropologia* supplement 66: 205–14.

———. 1999. The Early Neolithic Danish Bog Finds: A Strange Group of People! In *Bog Bodies, Sacred Sites and Wetland Archaeology,* ed. B. Coles, J. Coles, and M. S. Jørgensen, 27–32. Exeter (U.K.) Wetland Archaeology Research Project 12.

———. 2002. Palaeopathology as a Tool for a Study of Survival of Past Populations. In *Human Biology and History,* ed. M. Smith, 165–77. London and New York: Taylor and Francis.

Bennike, P., E. B. Bodzsar, and C. Susanne. 2002. *Ecological Aspects of Past Human Settlements in Europe.* Budapest: Eotvos University Press.

Bennike, P., and H. Bohr. 1990. Bone Mineral Content in the Past and Present. In *Osteoporosis,* ed. C. Christiansen and K. Overgaard, 89–91. Copenhagen: Osteopress.

Bennike, P., M. E. Lewis, H. Schutkowski, and F. Valentin. 2005. Comparison of Child Morbidity in Two Contrasting Medieval Cemeteries from Denmark. *American Journal of Physical Anthropology* (online).

Bense, J. A. 1994. *Archaeology of the Southeastern United States: Paleoindian to World War I.* San Diego, Calif.: Academic Press.

Benson, L., L. Cordell, K. Vincent, H. Taylor, J. Stein, G. L. Farmer, and K. Futa. 2003. Ancient Maize from Chacoan Great Houses: Where Was It Grown? *Proceedings of the National Academy of Sciences* 100: 13111–15.

Bently, G. R. 1996. How Did Prehistoric Women Bear "Man the Hunter"?: Reconstructing Fertility from the Archaeological Record. In *Gender and Archaeology*, ed. R. P. Wright, 23–51. Philadelphia: University of Pennsylvania Press.

Bently, G. R., R. R. Paine, and J. L. Boldsen. 2001. Fertility Changes with the Prehistoric Transition to Agriculture: Perspectives on Reproductive Ecology and Paleodemography. In *Reproductive Ecology and Human Evolution*, ed. P. T. Ellison, 203–31. New York: Aldine de Gruyter.

Benton, J. N. 1996. *Excavations at Al Sufouh: A Third Millennium Site in the Emirate of Dubai.* Brepols: Abiel.

Berbig, C., and R. Seifert. 1975. *Zahnmasse Menschlicher Populationen Hessens (BRD) aus dem Neolithikum und dem Mittelalterbis zur frühen Neuzeit.* Giessen: Justus Liebig Universität.

Berenguer, J., and P. Dauelsberg. 1989. El Norte Grande en la órbita Tiwanaku 400–1200 BC. In *Culturas de Chile: Prehistoria, desde sus orígenes hasta la civilización,* ed. J. Hidalgo, V. Schiappacasse, H. Niemeyer, C. Aldunate, S. Iván, 129–80. Santiago, Chile: Editorial Andrés Bello.

Berryman, H. E. 1980. Mouse Creek, Dallas, and Middle Cumberland: A Multivariate Approach. In *Skeletal Biology of Aboriginal Populations in the Southeastern United States,* ed. P. Willey and F. H. Smith. Tennessee Anthropological Association Miscellaneous Paper 5.

———. 1981. The Averbuch Skeletal Series: A Study of Biological and Social Stress in a Late Mississippian Period Site from Middle Tennessee. Ph.D. thesis, Department of Anthropology, University of Tennessee, Knoxville.

Betsinger, T. K. 2002. The Interrelationship of Status and Health in the Tellico Reservoir: A Biocultural Analysis. M.A. thesis, Department of Anthropology, University of Tennessee, Knoxville.

Bidwell, R., ed. 1971. *The Affairs of Arabia, 1905–1906.* Vol. 1. London: Frank Cass.

Bienert, H. D. 2001. The Pre-Pottery Neolithic B (PPNB) of Jordan: A First Step towards Proto-urbanism? *Studies in the History and Archaeology of Jordan* 7: 107–19.

Bird, J. B., J. Hyslop, and M. D. Skinner. 1985. *The Preceramic Excavations at the Huaca Prieta, Chicama Valley, Peru.* Anthropological Papers of the American Museum of Natural History 62. New York.

Blakely, R. L. 1980. Sociocultural Implications of Pathology between the Village Area and Mound C Skeletal Remains from Etowah, Georgia. In *The Skeletal Biology of Aboriginal Populations in the Southeastern United States,* ed. P. Willey and F. H. Smith, 28–38. Tennessee Anthropological Association Miscellaneous Paper 5.

Blakely, R. L., and L. Beck. 1984. The Human Skeletal Remains. In *The Plum Grove Site (40WG17), Washington County, Tennessee, Cherokee National Forest,* ed. R. Dickens. Ms. on file, Georgia State University Laboratory of Anthropology, Athens.

Blau, S. 1996. Attempting to Identify Activities in the Past: Preliminary Investigations of the Third Millennium BC Population at Tell Abraq. *Arabian Archeology and Epigraphy* 7: 143–76.

———. 1998. Finally the Skeleton: An Analysis of Archaeological Human Skeletal Remains from the United Arab Emirates. Ph.D. thesis, University of Sydney.

———. 1999a. The Human Elements: Skeletal Remains from Unar 2, Ras Al Khaimah. <http://www.rakmuseum.gov.ae/unar2bone.html>.

———. 1999b. Of Water and Oil: Exploitation of Natural Resources and Social Change in Eastern Arabia. In *The Prehistory of Food: Appetities for Change*, ed. C. Gosden and J. Hather, 83–98. London: Routledge.

———. 2001a. Limited Yet Informative: Pathological Alterations Observed on Human Skeletal Remains from Third and Second Millennia BC Collective Burials in the United Arab Emirates. *International Journal of Osteoarchaeology* 11: 173–205.

———. 2001b. Fragmentary Endings: A Discussion of Third Millennium BC Burial Practices in the Oman Peninsula. *Antiquity* 75: 557–70.

———. 2001c. Young and Alone: Discussions of an Articulated Third Millennium BC Burial at Tell Abraq, United Arab Emirates. *Adumatu* 3: 7–14.

Blitz, J. H. 1993. *Ancient Chiefdoms of the Tombigbee.* Tuscaloosa: University of Alabama Press.

Blitz, J. H., and C. B. Mann. 2000. *Fisherfolk, Farmers and Frenchmen: Archaeological Explorations on the Mississippi Gulf Coast.* Archaeological Report 30. Jackson: Mississippi Department of Archives and History.

Blom, D. E., J. E. Buikstra, P. D. Tomczak, L. Keng, E. Shoreman, and D. Stevens-Tuttle. 2005. Anemia and Childhood Mortality: Latitudinal Patterning along the Coast of Pre-Columbian Peru. *American Journal of Physical Anthropology* 127: 152–69.

Bocquentin, F. 2004. Pratiques Funéraires, Paramètres Biologiques et Identités Culturelles au Natoufien: Une Analyse Archéo-Anthropologique. Unpublished Ph.D. thesis, Universite Bordeaux I.

Bocquentin, F., P. Sellier, and P. Murail. 2001. La Population Natoufienne de Mallaha (Eynan, Israël): Dénombrement, age du décès et recrutement funéraire. *Paléorient* 27: 89–106.

Bocquet-Appel, J. P., and C. Masset. 1996. Paleodemography: Expectancy and False Hope. *American Journal of Physical Anthropology* 99: 571–83.

Bocquet-Appel, J. P., and S. Naji. 2006. Testing the Hypothesis of a World Wide Neolithic Demographic Transition. *Current Anthropology* 47 (2): 341–66.

Bogin, B., and R. Keep. 1999. Eight Thousand Years of Economic and Political History in Latin America Revealed by Anthropometry. *Annals of Human Biology* 264: 333–51.

Boldsen, J. L. 2001. Epidemiological Approach to the Paleopathological Diagnosis of Leprosy. *American Journal of Physical Anthropology* 115: 380–87.

Boucharlat, R., E. Haerinck, C. S. Philips, and D. T. Potts. 1988. Archaeological Reconnaissance at Ed-Dur, Umm al-Qaiwain, U.A.E. *Akkadica* 58: 1–26.

Boyd, C. C., P. A. Driscoll, and S. A. Symes. 1983. An Analysis of the Skeletal Remains from the Brown Site (40MR260), Marion County, Tennessee. *Tennessee Anthropologist* 8: 50–66.

Boyd, D. C. 1986. A Comparison of Mouse Creek Phase to Dallas and Middle Cumberland Culture Skeletal Remains. In *Skeletal Analysis in Southeastern Archaeology,* ed. J. E. Levy, 103–26. North Carolina Archaeological Council Publication 24. Raleigh.

Boyd, D. C., and C. C. Boyd. 1989. A Comparison of Tennessee Archaic and Mississippian Femoral Lengths and Midshaft Diameters: Subsistence Change and Postcranial Variability. *Southeastern Archaeology* 8: 107–16.

Boyd, W. E., and R. J. McGrath. 2001a. The Geoarcheology of the Prehistoric Ditched Sites of the Upper Mae Nam Mun Valley, NE Thailand, III: Late Holocene Vegetation History. *Paleobiology* 171: 307–28.

———. 2001b. Iron Age Vegetation Dynamics and Human Impacts on the Vegetation of the Upper Mun River Floodplain, N.E. Thailand. *New Zealand Geographer* 57: 8–19.

Brabant, H. 1971. Some Facts on the Human Dentition during the Megalithic Era. In *Dental Morphology and Evolution,* ed. A. A. Dahlberg, 283–97. Chicago: University of Chicago Press.

Brace, C. L. 1964. A Nonracial Approach towards the Understanding of Human Diversity. In *The Concept of Race,* ed. A. Montagu, 103–52. London: Collier-Macmillan.

———. 1980. Australian Tooth-Size Clines and the Death of a Stereotype. *Current Anthropology* 21: 141–64.

Brace, C. L., K. R. Rosenberg, and K. D. Hunt. 1987. Gradual Change in Human Tooth Size in the Late Pleistocene and Post-Pleistocene. *Evolution* 41 (4): 705–20.

Brace, C. L., S. L. Smith, and K. Hunt. 1991. What Big Teeth You Had Grandma! Human Tooth Size Past and Present. In *Advances in Dental Anthropology,* ed. M. A. Kelley and C. S. Larsen, 33–57. New York: Wiley-Liss.

Braun, M., D. C. Cook, and S. Pfeiffer. 1998. DNA from Mycobacterium Tuberculosis Complex Identified in North American, Pre-Columbian Human Skeletal Remains. *Journal of Archaeological Science* 25: 271–77.

Brenton, B. P., and R. R. Paine. 2000. Pellagra and Paleonutrition: Assessing the Diet and Health of Maize Horticulturists through Skeletal Biology. *Nutritional Anthropology* 23: 2–9.

Breuil, J. Y. 1999. The World's Largest Prehistoric Cemetery . . . In *Bahrain: The Civilisation of the Two Seas,* ed. Institut du Monde Arabe, 49–55. Ghent: Snoeck-Ducaju and Zoon.

Brickley, M., and R. Ives. 2006. Skeletal Manifestations of Infantile Scurvy. *American Journal of Physical Anthropology* 129: 163–72.

Brickley, M., and J. McKinley. 2004. *Guidelines to the Standards for Recording Human Remains.* Reading: British Association of Biological Anthropology and Osteoarchaeology and Institute of Field Archaeologists.

Bridges, P. S. 1989. Changes in Activities with the Shift to Agriculture in the Southeastern United States. *Current Anthropology* 30: 385–94.

———. 1994. Vertebral Arthritis and Physical Activities in the Prehistoric Southeastern United States. *American Journal of Physical Anthropology* 93: 83–93.

Bridges, P. S., J. H. Blitz, and M. C. Solano. 2000. Changes in Long Bone Diaphyseal Strength with Horticultural Intensification in West-Central Illinois. *American Journal of Physical Anthropology* 112 (2): 217–38.

Briggs, L. C., and N. L. Guede. 1964. *No More for Ever: A Saharan Jewish Town.* Papers of the Peabody Museum 55, no. 1. Cambridge, Mass.

Brimblecombe, P. 1975. Industrial Air Pollution in 13th Century Britain. *Weather* 30: 388–96.

———. 1978. Air Pollution in Industrialising England. *Journl of the Air Pollution Control Association* 28 (2): 115–18.

Bröste, K., J. B. Jørgensen, J. Becker, and J. Brøndsted. 1956. *Prehistoric Man in Denmark.* Copenhagen: Munksgaard.

Brothwell, D. R. 1972. *Digging Up Bones: The Excavation, Treatment and Study of Human Skeletal Remains.* 2nd ed. London: Trustees of the British Museum.

———. 1981. *Digging Up Bones.* London: British Museum of Natural History.

———. 1991. On Zoonoses and Their Relevance to Paleopathology. In *Human Paleopathology,* ed. D. J. Ortner and A. C. Aufderheide, 18–22. Washington, D.C.: Smithsonian Institution Press.

Brown, T., S. K. Pinkerton, and W. Lambert. 1979. Thickness of the Cranial Vault in Australian Aboriginals. *Archives of Physical Anthropology in Oceania* 14: 54–71.

Brues, A. M. 1977. *People and Races.* New York: Macmillan.

Buikstra, J. E. 1976. Differential Diagnosis: An Epidemiological Model. *Yearbook of Physical Anthropology* 20: 316–28.

———. 1984. The Lower Illinois River Region: A Prehistoric Context for the Study of Ancient Health and Diet. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 215–34. Orlando, Fla.: Academic Press.

———. 1992. Diet and Disease in Late Prehistory. In *Disease and Demography in the Americas,* ed. J. W. Verano and D. H. Ubelaker, 87–102. Washington, D.C.: Smithsonian Institution Press.

Buikstra, J. E., J. Bullington, D. C. Charles, D. C. Cook, S. K. Frankenberg, L. W. Konigsberg, J. B. Lambert, and L. Xue. 1987. Diet, Demography and the Development of Horticulture. In *Emergent Horticultural Economies of the Eastern Woodlands,* ed. W. F. Keegan, 76–85. Center for Archaeological Investigation Occasional Paper 7. Carbondale: Southern Illinois University Press.

Buikstra, J. E., and D. C. Cook. 1980. Paleopathology: An American Account. *Annual Review of Anthropology* 9: 433–70.

———. 1978. Pre-Columbian Tuberculosis: An Epidemiological Approach. *Medical College of Virginia Quarterly* 14: 32–44.

———. 1981. Pre-Columbian Tuberculosis in West-Central Illinois: Prehistoric Disease in Biocultural Perspective. In *Prehistoric Tuberculosis in the Americas,* ed. J. E. Buikstra, 115–39. Northwestern University Archeological Program Scientific Papers 5, Evanston, Ill.

Buikstra, J. E., and L. W. Konigsberg. 1985. Paleodemography: Critiques and Controversies. *American Anthropologist* 87: 316–33.

Buikstra, J. E., L. W. Konigsberg, and J. Bullington. 1986. Fertility and the Development of Agriculture in Prehistoric Midwest. *American Antiquity* 51: 528–46.

Buikstra, J. E., J. C. Rose, and G. R. Milner. 1994. A Carbon Isotopic Perspective on Dietary Variation in Late Prehistoric Western Illinois. In *Agricultural Origins and Development in the Midcontinent,* ed. W. Green, 155–70. Office of the State Archaeologist Report 19. Iowa City: University of Iowa.

Buikstra, J. E., and D. H. Ubelaker, eds. 1994. *Standards for Data Collection from Human Skeletal Remains.* Arkansas Archeological Survey Research Series 44. Fayetteville.

Buikstra, J. E., and S. Williams. 1991. Tuberculosis in the Americas: Current Perspectives. In *Human Paleopathology,* ed. D. J. Ortner and A. C. Aufderheide, 161–72. Washington, D.C.: Smithsonian Institution Press.

Bulbeck, F. D. 1981. Continuities in Southeast Asian Evolution since the Late Pleistocene: Some New Material Described and Some Old Questions Reviewed. M.A. thesis, Australian National University, Canberra.

———. 2005. The Gua Cha Burials. In *The Perak Man and Other Prehistoric Skeletons of Malaysia,* ed. Zuraina Majid, 253–309. Pulau Pinang: Penerbit Universiti Sains Malaysia.

Bullington, J. 1991. Deciduous Dental Microwear of Prehistoric Juveniles from the Lower Illinois River Valley. *American Journal of Physical Anthropology* 84 (1): 59–73.

Burger, R. L. 1987. The U-shaped Pyramid Complex, Cardal, Peru. *National Geographic Research* 3: 363–75.

———. 1992. *Chavin and the Origins of Andean Civilization.* London: Thames and Hudson.

Burger, R. L., and L. Salazar-Burger. 1991. The Second Season of Investigations at the Initial Period Center of Cardal, Peru. *Journal of Field Archaeology* 18: 275–96.

Burger, R. L., and N. J. van der Merwe. 1990. Maize and the Origin of Highland Chavín Civilization: An Isotopic Perspective. *American Anthropologist* 92: 85–95.

Cai, L., and S. Qiu. 1984. Carbon-13 Evidence for Ancient Diets in China. *Kaogu* 10: 945–55. (In Chinese.)

Calcagno, J. M. 1986. Dental Reduction in Post-Pleistocene Nubia. *American Journal of Physical Anthropology* 70: 349–64.

———. 1989. *Mechanisms of Human Dental Reduction: A Case Study from Post-Pleistocene Nubia.* Publications in Anthropology 18. Lawrence: University of Kansas.

Calcagno, J. M., and K. R. Gibson. 1991. Selective Compromise: Evolutionary Trends and Mechanisms in Hominid Tooth Size. In *Advances in Dental Anthropology,* ed. M. A. Kelley and C. S. Larsen, 59–76. New York: Wiley Liss.

Carey, S. L. 1965. A Unique Epidemic of Tuberculosis: Eskimo Point, 1963. *American Review of Respiratory Diseases* 91: 479–87.

Carmichael, A. 1983. Infection, Hidden Hunger and History. *Journal of Multidisciplinary History* 14: 249–64.

Carter, R. A. 1997. Defining the Late Bronze Age in Southeast Arabia: Ceramic Evolution and Settlement during the Second Millennium BC. Ph.D. thesis, Institute of Archaeology, University College London.

Cassidy, C. M. 1984. Skeletal Evidence for Prehistoric Subsistence Adaptation in the Central Ohio Valley. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 307–45. Orlando, Fla.: Academic Press.

Cavalli-Sforza, L. L., P. Menozzi, and A. Piazza. 1994. *The History and Geography of Human Genes.* Princeton, N.J.: Princeton University Press.

Cerling, T. E., and J. M. Harris. 1999. Carbon Isotope Fractionation between Diet and Bioapatite in Ungulate Mammals and Implications for Ecological and Paleoecological Studies. *Oecologia* 120: 347–63.

Cerling, T. E., J. A. Hart, and T. B. Hart. 2004. Stable Isotope Ecology in the Ituri Forest. *Oecologia* 138: 5–12.

Champion, T. C. 1999. The Later Bronze Age. In *The Archaeology of Britain. An Introduction from the Upper Paleolithic to the Industrial Revolution*, ed. J. R. Hunter and I. Ralston, 95–112. London: Routledge.

Chang, K. C. 1986. *The Archaeology of Ancient China,* 4th ed. Cambridge, Mass.: Harvard University Press.

Chapman, J., and A. B. Shea. 1981. The Archaeobotanical Record: Early Archaic Period to Contact in the Lower Little Tennessee River Valley. *Tennessee Archaeologist* 6: 61–84.

Chen, B., X. Wang, and J. Zhang. 1995b. Finds and Morphological Analysis of Carbonized Rice in the Jianhu Neolithic Site in Wuyang County, Henan Province. *Chinese Journal of Rice Science* 9: 129–34. Translated by L. Zhang and B. Gordon.

Chen, B., J. Zhang, and H. Lu. 1995a. Discovery of Rice Phytoliths in the Neolithic Site at Jianhu of Henan Province and Its Significance. *Chinese Science Bulletin* 40: 14. Translated by L. Zhang.

Christensen, A. F. 1998. Odontometric Microevolution in the Valley of Oaxaca, Mexico. *Journal of Human Evolution* 34: 333–60.

Churchill, S. E. 1998. Cold Adaptation, Heterochronomy, and Neandertals. *Evolution and Anthropology* 7 (2): 46–61.

Clarke, N. G., S. E. Carey, E. Srikandi, R. S. Hirsh, and P. I. Leppard. 1986. Periodontal Disease in Ancient Populations. *American Journal of Physical Anthropology* 71: 173–83.

Clayton, F. H. 2003. Weaning Patterns in the Later Stone Age as Reconstructed through Nitrogen Isotope Analyses of the Skeleton from Matjes River Rock Shelter. M.S. thesis, University of Cape Town, Cape Town.

Clayton, F. H., J. Sealy, and S. Pfeiffer. 2006. Weaning Age among Foragers at Matjies River Rock Shelter, South Africa, from Stable Nitrogen and Carbon Isotope Analyses. *American Journal of Physical Anthropology* 129: 311–17.

Cohen, M. N. 1989. *Health and the Rise of Civilization.* New Haven, Conn.: Yale University Press.

———. 1997. Does Paleopathology Measure Community Health. In *Integrating Archaeological Demography,* ed. R. R. Paine, 242–61. Center for Archaeological Investigations, Southern Illinois University at Carbondale, Occasional Paper 24.

Cohen, M. N., and G. J. Armelagos, eds. 1984. *Paleopathology at the Origins of Agriculture.* Orlando, Fla.: Academic Press.

Colledge, S., J. Conolly, and S. Shennan. 2004. Archaeobotanical Evidence for the Spread of Farming in the Eastern Mediterranean. *Current Anthropology* 45: 35–58.

Colonias, L. 2002. Death on the River: Paleopathology of the Williams Landing Site (1JA306), Jackson County, Alabama. M.A. thesis, Department of Anthropology and Sociology, University of Southern Mississippi, Hattiesburg.

Conner, M. D. 1990. Population Structure and Skeletal Variation in the Late Woodland of West-Central Illinois. *American Journal of Physical Anthropology* 82 (1): 31–43.

Constandse-Westermann, T. S., and R. R. Newell. 1984. Human Biological Background of Population Dynamics in the Western European Mesolithic. *Human Palaeontology Proceedings Series B* 87: 139–223.

Cook, D. C. 1976. Schild Pathologies. In *Spatial Structure and Social Organization: Regional Manifestations of Mississippian Society,* ed. L. G. Goldstein, 353–58. Doctoral dissertation, Northwestern University, Evanston, Ill.

———. 1979. Subsistence Base and Health in Prehistoric Illinois River Valley: Evidence from the Human Skeleton. *Medical Anthropology* 3: 109–24.

———. 1980. Schild Pathologies. In *Mississippian Mortuary Practices: A Case Study of Two Cemeteries in the Lower Illinois Valley,* ed. L. G. Goldstein, 160–63. Northwestern University Archeological Program Scientific Papers 3, Evanston, Ill.

———. 1984. Subsistence and Health in the Lower Illinois Valley: Osteological Evidence. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 237–69. Orlando, Fla.: Academic Press.

Cook, D. C., and J. E. Buikstra. 1979. Health and Differential Survival in Prehistoric Populations: Prenatal Dental Defects. *American Journal of Physical Anthropology* 51: 649–64.

Coon, C. S. 1965. *The Living Races of Man.* New York: Alfred A. Knopf.

Coppa, A., R. Macchiarelli, S. Salvatori, and G. Santini. 1985. The Prehistoric Graveyard of Ra's al-Hamra (RH5): A Short Preliminary Report on the 1981–83 Excavations. *Journal of Oman Studies* 8 (1): 97–102.

Corporación Tiempo 2000. 1993. *I: Región de Tarapacá.* Serie Cuadernos Regionales. Santiago, Chile: CORFO.

Corruccini, R. S., J. S. Handler, R. J. Mutaw, and F. W. Lange. 1982. Osteology of a Slave Burial Population from Barbados, West Indies. *American Journal of Physical Anthropology* 59: 443–59.

Corruccini, R. S., and R. H. Potter. 1981. Developmental Correlates of Crown Component Asymmetry and Occlusal Discrepancy. *American Journal of Physical Anthropology* 55: 21–31.

Corruccini, R. S., and K. Sharma. 1989. Odontometric Asymmetry in Punjabi Twins

with Special Reference to Methods for Detecting Spurious Genetic Variance. *Archives of Oral Biology* 34: 839–41.

Corruccini, R. S., K. Sharma, and R. H. Potter. 1988. Comparative Genetic Variance of Dental Size and Asymmetry in U.S. and Punjabi Twins. In *Teeth Revisited: Proceedings of the VIIth International Symposium on Dental Morphology,* ed. D. E. Russel, J. P. Santoro, and D. Sigogneau-Russel, 47–53. Mus. National d'Histoire Naturelle 53 (ser. C). Paris.

Cranbrook, Earl of. 2000. Northern Borneo Environments of the Past 40,000 Years: Archaeozoological Evidence. *Sarawak Museum Journal* 55: 61–109.

Crane-Kramer, G. M. M. 2002. Was There a Medieval Diagnostic Confusion between Leprosy and Syphilis: An Examination of the Skeletal Evidence. In *The Past and Present of Leprosy: Proceedings of the 3rd International Congress on the Evolution and Palaeoepidemiology of the Infectious Diseases,* ed. C. Roberts, M. E. Lewis, and K. Manchester, 112–22. Oxford, U.K.: Archaeopress.

Crawford, G., A. Underhill, Z. Zhao, G.-A. Lee, G. Feinman, L. Nicholas, F. Luan, H. Yu, H. Fang, and F. Cai. 2005. Late Neolithic Plant Remains from Northern China: Preliminary Results from Liangchengzhen, Shandong. *Current Anthropology* 46: 309–17.

Crawford, H. 1998. *Dilmun and Its Neighbours.* Cambridge, U.K.: Cambridge University Press.

Cree, T. C., and D. S. Schalch. 1985. Protein Utilization in Growth: Effect of Lysine Deficiency on Serum Growth Hormone, Somatomedins, Insulin, Total Thyroxine (T4) and Triiodothyronine, Free T4 Index, and Total Corticosterone. *Endocrinology* 117: 667–73.

Crubézy, E., J. Bruzek, and J. Guilane. 2002. The Transition to Agriculture in Europe. In *Ecological Aspects of Past Human Settlements in Europe,* ed. P. Bennike, E. B. Bodzsar, and S. Charles, 93–110. Budapest: Eotvos University Press.

Crubézy, E., J. Bruzek, J. Guilaine, E. Cunha, D. Rougé, J. Jelinek. 2001. The Antiquity of Cranial Surgery in Europe and in the Mediterranean Basin. Comptes Rendue de l'Academie des Sciences Paris. *Sciences de la Terre et des Planètes* 332: 417–23.

Cunha, E., and F. Cardoso. 2001. The Osteological Series from Cabeço da Amoreira (Muge, Portugal). *Bulletin et Mémories de la Société d'Anthropologie de Paris* n.s. 13 (3–4): 323–33.

———. 2002–3. New Data on Muge Shell Middens: A Contribution to More Accurate Numbers and Dates. *Muge Estudos Arqueológicos* 1: 171–84.

Cunha, E., F. Cardoso, and C. Umbelino. 2003. Inferences about Life Style on the Basis of Anthropological Data: The Case of the Portuguese Shell Middens. In *Mesolithic on the Move,* ed. L. Larsson, H. Hindgren, K. Knuttson, D. Loeffler, and A. Akerlund, 184–88. Woodbridge and London: Oxbow Books.

Cunha, E., and C. Umbelino. 1995–97. Abordagem Antropológica das Comunidades Mesolíticas dos Concheiros do Sado. *Arqueólogo Português* series 4, 13–15: 161–79.

———. 2001. The Mesolithic People from Portugal. *Anthropologie (Brno)* 39 (2–3): 125–32.

Cunha, E., C. Umbelino, and F. Cardoso. 2004. About Violent Interactions in the Mesolithic: The Absence of Evidence from the Portuguese Shell Middens. In *Violent Interactions in the Mesolithic,* ed. M. Roksandic, 41–46. BAR International Series 1237. Oxford: British Archaeological Reports.

Curren, C. B. 1976. Prehistoric and Early Historic Occupation of the Mobile Bay and Mobile Delta Area of Alabama with an Emphasis on Subsistence. *Journal of Alabama Archaeology* 22: 61–84.

Curtin, P. D. 2002. Overspecialization and Remedies. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 603–8. Cambridge, U.K.: Cambridge University Press.

Cushing, F. H. 1920. *Zuni Breadstuff.* Indian Notes and Monographs 8. New York: Museum of the American Indian, Heye Foundation.

Dai, X. 1998. The Development of the Neolithic Cultures in the Middle Reaches of the Yellow River. *Kaogu Xuebao* 4: 389–418.

Dailey, R. C. 1974. Analysis of the Human Remains from the Mangum Site (22Cb584), Claiborne Co., Mississippi. Ms. on file, Department of Anthropology, Florida State University, Tallahassee.

Dalongeville, R. 1999. Bahrain, the Gulf's Natural Exception. In *Bahrain: The Civilisation of the Two Seas,* ed. Institut du Monde Arabe, 28–32. Ghent: Snoeck-Ducaju and Zoon.

Danforth, M. E. 1996. Health Patterns at a Small Mississippian Village: The Kellogg Site. Paper presented at the annual meeting of the Southeastern Archaeological Conference, Birmingham.

———. 1997. Late Classic Maya Health Patterns: Evidence from Enamel Microdefects. In *Bones of the Maya,* ed. S. L. Whittington and D. M. Reed, 127–33. Washington, D.C.: Smithsonian Institution Press.

———. 1999a. Coming Up Short: Stature and Nutrition in Prehistoric Maya. In *Reconstructing Ancient Maya Diet,* ed. C. D. White, 103–17. Salt Lake City: University of Utah Press.

———. 1999b. Nutrition and Politics in Prehistory. *Annual Review of Anthropology* 28: 1–25.

———. 2003. Bioarchaeological Analysis of Prehistoric Human Remains Recovered on the Mississippi-Alabama Gulf Coast. Ms. on file, Department of Anthropology and Sociology, University of Southern Mississippi, Hattiesburg.

———. 2004. Analysis of Prehistory of Human Remains from Mississippi Curated at the Smithsonian Institution. Final report submitted to the Aubrey and Ella Lucas Endowment for Faculty Excellence, University of Southern Mississippi, Hattiesburg.

Danforth, M. E., K. L. Burleigh, E. Garner, T. D. Hensley, and E. M. Outlaw. n.d. The Human Remains from the Humber Site (22Co601), Coahoma Co, Mississippi. Ms. on file, Department of Anthropology and Sociology, University of Southern Mississippi, Hattiesburg.

Danforth, M. E., T. D. Hensley, D. C. Martin, M. D. Page, A. Santure, A. Thompson, and D. B. Zivin. 2007. A Bioarchaeological Analysis of Selected Prehistoric Populations from the Mississippi Delta. Manuscript on File, Dept. of Anthropology and Sociology, University of Southern Mississippi, Hattiesburg.

Danforth, M. E., K. P. Jacobi, and G. D. Wrobel. 2002. A Database of Bioarchaeological Studies of Prehistoric Skeletal Populations from Mississippi and Alabama. Paper presented at the annual meeting of the Southeastern Archaeological Conference, Biloxi.

Dark, P. 2000. *The Environment of Britain in the 1st Millennium.* London: Duckworth.

Darvill, T. 1987. *Prehistoric Britain.* London: Batsford.

Dauelsberg, P. 1992–93. Prehistoria de Arica. *Diálogo Andino* 11–12: 9–31.

Deacon, H. J., and J. Deacon. 1999. *Human Beginnings in South Africa.* Cape Town: David Phillip Publishers.

Deacon, J., and N. Lancaster. 1988. *Later Quaternary Paleoenvironments of Southern Africa.* Oxford, U.K.: Clarendon Press.

De Blij, H. J., and P. O. Muller. 2002. *Geography: Realms, Regions, and Concepts.* New York: J. Wiley and Sons.

Delgado, M. 1992. Investigaciones en Villa El Salvador. *Pachacamac, Revista del Museo de la Nacion* 1 (1):35–36. Lima

———. 1994. *Rescate Arqueológico Informe Final: Proyecto Investigaciones Arqueológicas en Villa El Salvador.* Lima: Universidad Nacional Mayor de San Marcos.

Denbow, J. R. 1999. Material Culture and the Dialectics of Identity in the Kalahari, AD 700–1700. In *Beyond Chiefdoms: Pathways to Complexity in Africa,* ed. S. K. McIntosh, 110–23. Cambridge, U.K.: Cambridge University Press.

DeNiro, M. J. 1985. Postmortem Preservation and Alteration of In-Vivo Bone Collagen Isotope Ratios in Relation to Paleodietary Reconstruction. *Nature* 317: 806–9.

Deuschle, K. W. 1960. Tuberculosis among the Navajo. *American Review of Respiratory Diseases* 80: 200–206.

Dewar, G., and S. Pfeiffer. 2004. Postural Behavior of Later Stone Age People in South Africa. *South African Archaeological Bulletin* 59: 52–58.

Dhavalikar, M. K. 1984. Toward an Ecological Model for Chalcolithic Cultures of Central and Western India. *Journal of Anthropological Archaeology* 3: 133–58.

———. 1985. Cultural Ecology of Chalcolithic Maharashtra. In *Recent Advances in Indian Archaeology,* ed. S. B. Deo and K. Paddayya, 65–73. Poona: Deccan College Post-Graduate and Research Institute.

———. 1989a. Farming to Pastoralism: Effects of Climate Change in the Deccan. In *The Walking Larder: Patterns of Domestication, Pastoralism, and Predation,* ed. J. Clutton-Brock, 156–68. London: Unwin Hyman.

———. 1989b. Human Ecology in Western India in the Second Millennium BC. *Man and Environment* 14: 83–90.

Dickel, D. N. 1991. Descriptive Analysis of the Skeletal Collection from the Prehistoric Manasota Key Cemetery, Sarasota County, Florida (8SO1292). Florida Department of State, Bureau of Archaeological Research, Florida Archaeological Reports, Tallahassee.

Dietz, M. J., and R. A. Bergfield. 2001. Deterioration of Health and Early Agricultural Dependence in Southern Coastal Peru. *American Journal of Physical Anthropology* supplement 32: 59.

Dobson, A. P., and R. Carper. 1996. Infectious Disease and Human Population History. *BioScience* 46: 115–26.

Dodo, Y., and H. Ishida. 1987. Incidence of Nonmetric Cranial Variants in Several Population Samples from East Asia and North America. *Journal of the Anthropological Society of Nippon* 95: 161–77.

Doe, D. B., and B. de Cardi. 1983. Archaeological Survey in Southern Ras al-Khaimah, 1982. *Proceedings of the Seminar for Arabian Studies* 13: 31–35.

Domett, K. 2001. *Health in Late Prehistoric Thailand.* BAR International Series 946. Oxford: Archaeopress.

Domett, K., and N. Tayles. 2006. Adult Fracture Patterns in Prehistoric Thailand: A Biocultural Interpretation. *International Journal of Osteoarchaeology* 16 (3): 185–99.

Doran, G. H. 1975. The Long Bones of the Texas Indians. Master's thesis, University of Texas, Austin.

———. 1980. Paleodemography of the Plains Miwok Ethnolinguistic Area. Ph.D. dissertation, University of California–Davis.

———, ed. 2002a. *Windover: Multidisciplinary Investigations of an Early Archaic Florida Cemetery.* Gainesville: University Presses of Florida.

———. 2002b. A Paleodemographic Perspective. In *Windover: Multidisciplinary Investigations of an Early Archaic Florida Cemetery,* ed. G. H. Doran, 265–80. Gainesville: University Presses of Florida.

———. 2002c. The Windover Radiocarbon Chronology. In *Windover: Multidisciplinary Investigations of an Early Archaic Florida Cemetery,* ed. G. H. Doran, 59–72. Gainesville: University Presses of Florida.

Doran, G. H., D. N. Dickel, W. W. Ballinger Jr., O. F. Agee, P. J. Laipis, and W. W. Hauswirth. 1986. Anatomical, Cellular and Molecular Analysis of 8,000-yr-old Human Brain Tissue from the Windover Archaeological Site. *Nature* 323: 803–6.

Doran, G. H., D. N. Dickel, and L. Newsom. 1990. A 7,290-Year-Old Bottle Gourd from the Windover Site, Florida. *American Antiquity* 55 (2): 354–60.

Douglas, M. T. 1996. Paleopathology in Human Skeletal Remains from the Pre-metal, Bronze, and Iron Ages, Northeastern Thailand. Ph.D. diss., University of Hawai'i, Honolulu. Ann Arbor: University Microfilms.

———. 2006. Subsistence Change and Dental Health in the People of Non Nok Tha, Northeast Thailand. In *Bioarchaeology of Southeast Asia,* ed. M. F. Oxenham and N. Tayles, 191–219. Cambridge, U.K.: Cambridge University Press.

Drake, D. L. 1989. Composition of Foods: Cereal Grains and Pasta; Raw, Processed, Prepared. In *Agriculture Handbook,* 8–20. Washington, D.C.: U.S. Department of Agriculture.

Drennan, M. R. 1929. The Dentition of a Bushman Tribe. *Annals of the South African Museum* 24: 63–88.

Driver, H. E. 1961. *Indians of North America.* Chicago: University of Chicago Press.

Drusini, A. G. 1991. Skeletal Evidence of Three Pre-Columbian Coastal People from Nasca, Peru. *Homo* 42 (2): 150–62.

Duran, P. E., S. Upadhya, and G. J. Armelagos. 1997. Analysis of Stature and Sexual Dimorphism in Two Ancient Sudanese Nubian Populations: Meroitic and X-Group. Paper presented to the 66th Annual Meeting of the American Association of Physical Anthropologists.

Dutour, O., G. Palfi, J. Berato, and J. P. Brun. 1993. *The Origin of Syphilis in Europe: Before or After 1493.* Toulon/Paris: Centre Archaeologique du Var. Editions Errance.

Dyer, C. 1989. *Standards of Living in the Middle Ages: Social Change in England, 1200–1520.* Cambridge, U.K.: Cambridge University Press.

Earle, T. K. 1972. Lurin Valley, Peru: Early Intermediate Period Settlement Development. *American Antiquity* 37: 467–77.

Eaton, S. B., and S. B. Eaton. 1999. Hunter-Gatherers and Human Health. In *The Cambridge Encyclopedia of Hunters and Gatherers,* ed. R. B. Lee and R. Daly, 449–55. Cambridge, U.K.: Cambridge University Press.

Edwards, D. S. 1984. Dental Attrition and Subsistence at the Preceramic Site of Paloma, Peru. M.A. thesis, University of Missouri–Columbia.

Egnatz, D. 1983. Appendix A: Analysis of Human Skeletal Material from Mound C. In *Excavations at the Lake George Site, Yazoo County, Mississippi, 1958–1960,* ed. S.

Williams and J. P. Brain, 421–41. Papers of the Peabody Museum of Archaeology and Ethnology 74. Cambridge, Mass.: Harvard University.

Eisenach, K. D., M. D. Cave, J. H. Bates, and J. T. Crawford. 1990. Polymerase Chain Reaction Amplification of a Repetitive DNA Sequence Specific for Mycobacterium Tuberculosis. *Journal of Infectious Disease* 161: 977–81.

Eisenberg, L. E. 1991. Mississippian Cultural Terminations in Middle Tennessee: What the Bioarchaeological Evidence Can Tell Us. In *What Mean These Bones? Studies in Southeastern Bioarchaeology,* ed. P. S. Bridges, M. L. Powell, and A. M. W. Mires, 70–88. Tuscaloosa: University of Alabama Press.

El-Najjar, M. 1979. Human Treponematosis and Tuberculosis. *American Journal of Physical Anthropology* 51: 599–618.

———. 1985. An Anthropological Study on Skeletal Remains from Tomb A Hili North. *Archaeology in the United Arab Emirates* 4: 38–42.

El-Najjar, M., A. Al-Shiyab, and I. Al-Sarie. 1997. Cases of Tuberculosis at ʿAin Ghazal, Jordan. *Paléorient* 22: 123–28.

El-Najjar, M., M. Desantis, L. Ozebek. 1978. Prevalence and Possible Etiology of Dental Enamel Hypoplasia. *American Journal of Physical Anthropology* 48: 185–92.

Engel, F. A. 1963. *A Preceramic Settlement on the Central Coast of Peru: Asia, Unit 1.* Transactions of the American Philosophical Society 53, Philadelphia.

———. 1970. Exploration of the Chilca Canyon, Peru. *Current Anthropology* 11(1): 55–58.

———. 1980. *Prehistoric Andean Ecology.* Atlantic Highlands, N.J.: Humanities Press.

Enlow, D. H. 1982. *Handbook of Facial Growth.* Philadelphia: W. B. Saunders.

Eriksson, G. 2003. Norm and Difference: Stone Age Dietary Practice in the Baltic Region. Ph.D. dissertation, Archaeological Research Laboratory, Stockholm University, Stockholm.

Eshed, V. 2001. From Foraging to Farming in the Holocene: The Pre-Pottery Neolithic period (8300–5600 BC). In The Southern Levant: The Skeletal Evidence. Unpublished Ph.D. thesis, Tel Aviv University. (In Hebrew.)

Eshed, V., A. Gopher, T. B. Gage, and I. Hershkovitz. 2004a. Has the Transition to Agriculture Reshaped the Demographic Structure of Prehistoric Populations? New Evidence from the Levant. *American Journal of Physical Anthropology* 124: 315–29.

Eshed, V., A. Gopher, E. Galili, and I. Hershkovitz. 2004b. Musculoskeletal Stress Markers in Natufian Hunter-Gatherers and Neolithic Farmers in the Levant: The Upper Limb. *American Journal of Physical Anthropology* 123: 303–15.

Eshed, V., A. Gopher, and I. Hershkovitz. 2006. Tooth Wear and Dental Pathology at the Advent of Agriculture: New Evidence from the Levant. *American Journal of Physical Anthropology*. 130: 145–59.

Estes, A. 1988. Non-invasive Investigation of Skeletal Stress Markers in an Archaic Population from Central Florida (8BR246). M.A. thesis, Florida State University, Tallahassee.

Fairgrieve, S. I., and J. E. Molto. 2000. Cribra Orbitalia in Two Temporally Disjunct Population Samples from the Dakleh Oasis, Egypt. *American Journal of Physical Anthropology* 111: 319–31.

Falk, N., R. H. Tykot, M. Delgado, E. A. Pechenkina, and J. Vradenburg. 2004. Differential Subsistence Adaptations of Agriculturalists and Herders of the Early Intermediate Period in the Lurín Valley, Peru: New Data from Stable Isotope Analysis. *American Journal of Physical Anthropology* 123 (38): 93.

Fan, Wenquan. 2000. A Fruitful Excavation at the Guanjia Site. *Zhongguo Wenwubao* 26: 1.

Food and Agriculture Organization (FAO). 1972. *Food Composition Table for Use in East Asia.* Rome: Food and Agriculture Organization, Food Policy and Nutrition Division.

Fash, W. L. 2001. *Scribes, Warriors, and Kings.* Rev. ed. London: Thames and Hudson.

Ferembach, D. 1969. Etude Anthropologique des Ossements Humains Neolithiques de Tell-Ramad, Syrie. *Annals of Archaeology Arabes Syriennes* 19: 49–70.

Finke, L., H. Bruchhaus, and U. Jaeger. 2002. Dental Anthropological Investigations of Neolithic Skeletal Material in the Area of the Middle Elbe and Saare River, Germany. In *Ecological Aspects of Past Human Settlements in Europe,* ed. P. Bennike, E. B. Bodzsar, and C. Susanne, 223–33. Budapest: Eotvos University Press, European Anthropological Association.

Fischer, A. 2002. Food for Feasting? An Evaluation of Explanations of the Neolithisation of Denmark and Southern Sweden. In *The Neolithisation of Denmark: 150 Years of Debate,* ed. A. Fischer and K. Kristiansen, 341–93. Sheffield, U.K.: JR Collins.

Fish, J., and C. A. Lockwood. 2003. Dietary Constraints on Encephalization in Primates. *American Journal of Physical Anthropology* 120: 171–81.

Fitzgerald, C. M., and J. C. Rose. 2000. Reading between the Lines: Dental Development and Subadult Age Assessment Using Microstructural Growth Markers of Teeth. In *Biological Anthropology of the Human Skeleton,* ed. M. A. Katzenberg and S. R. Saunders, 163–86. New York: Wiley Liss.

Flores, I. 1981. *Investigaciones Arqueológicas en la Huaca Juliana, Miraflores-Lima.* Boletín de Lima 13: 65–70.

Focacci, G. 1974. Excavaciones en el Cementerio Playa Miller 7. *Chungara* 3: 23–74.

———. 1985. *Sociedades Aldeanas en el Periodo Medio y su Relación con el Imperio Tiwanaku.* Santiago, Chile: Serie Patrimonio Cultural Chileno.

———. 1989. Excavaciones Arqueológicas en el Cementerio AZ-6 Valle de Azapa, part 1, Fase Cabuza. *Chungara* 24–25: 69–23.

Focacci, G., and S. Chacón. 1989. Excavaciones Arqueológicas en los Faldeos del Morro de Arica: Sitios Morro 1/6 y 2/2. *Chungara* 22: 15–62.

Formicola, V. 1987. Neolithic Transitions and Dental Changes: The Case of an Italian Site. *Journal of Human Evolution* 16: 231–39.

Fortier, A. C., and D. K. Jackson. 2000. The Formation of a Late Woodland Heartland in the American Bottom, Illinois, ca. AD 650–900. In *Late Woodland Societies: Tradition and Transformation across the Midcontinent,* ed. T. E. Emerson, D. L. McElrath, and A. C. Fortier, 123–48. Lincoln: University of Nebraska Press.

Frantz, D. M. 1989. The Investigation and Analysis of Changes in Bone Fracture Frequencies for Selected Prehistoric Populations. M.A. thesis, Florida State University, Tallahassee.

Fraser, F. C. 1994. Developmental Instability and Fluctuating Asymmetry in Man. In *Developmental Instability: Its Origins and Evolutionary Implications,* ed. T. A. Markow, 319–34. Dordrecht: Kluwer Academic Publishers.

Frayer, D. W. 1978. *Evolution of the Dentition in Upper Palaeolithic and Mesolithic Europe.* Lawrence: University of Kansas Publications in Anthropology 10.

———. 1984. Biological and Cultural Change in the European Late Pleistocene and Early Holocene. In *The Origins of Modern Humans: A World Survey of the Fossil Evidence,* ed. F. H. Smith and F. Spencer, 211–50. New York: Alan R. Liss.

Frayer, D. W., and M. H. Wolpoff. 1985. Sexual Dimorphism. *Annual Review of Anthropology* 14: 429–73.

Fredericksen, B. K. 2000. Subsistence Reconstruction in the Tombigbee River Valley Using Dental Microwear and Environmental Scanning Electron Microscopy. M.A. thesis, Department of Anthropology and Sociology, University of Southern Mississippi, Hattiesburg.

Freund, A. 1939. The Problem of Tuberculosis in Palestine. *Medical Leaves* 2: 38–48.

Fritz, G., and T. R. Kidder. 1993. Subsistence and Social Change in the Lower Mississippi Valley: The Reno Brake and Osceola Sites, Louisiana. *Journal of Field Archaeology* 20: 281–90.

Frohlich, B. 1986. The Human Biological History of the Early Bronze Age Population in Bahrain. In *Bahrain through the Ages: The Archaeology,* ed. H. Al Khalifa and M. Rice, 47–63. London: KPI.

Froment, A. 2002. The Biological Evolution of Populations during the Early Holocene Transitions. In *Ecological Aspects of Past Human Settlements in Europe,* ed. P. Bennike, E. B. Bodzsar, and C. Susanne, 41–60. Budapest: Eotvos University Press.

Fujita, M., E. A. Roth, A. M. Nathan, and E. Fratkin. 2004. Sedentism, Seasonality and Economic Status: A Multivariate Analysis of Maternal Dietary and Health Statuses between Pastoral and Agricultural Ariaal and Redille Communities in Northern Kenya. *American Journal of Physical Anthropology* 123: 277–91.

Fusegawa, H., B. H. Wang, K. Sakurai, K. Nagasawa, M. Okauchi, and K. Nagakura. 2003. Outbreak of Tuberculosis in a 2000-Year-Old Chinese Population. *Kansenshogaku Zasshi* 77: 146–49. *Wenwu* 1: 1–17.

Galili, E., B. Rosen, A. Gopher, and L. K. Horwitz. 2003. The Emergence and Dispersion of the Eastern Mediterranean Fishing Village: Evidence from Submerged Neolithic Settlements off the Carmel Coast, Israel. *Journal of Mediterranean Archeology* 15: 167–98.

Gama, R. P., and E. Cunha. 2003. A Neolithic Case of Cranial Trepanation: Eira-Pedrinha-Portugal. In *Cranial Trepanation in Human History,* ed. R. Arnott, S. Finger, and C. Smith, 131–36. Lisse: Swets and Zeitlinger.

Gardner, J. A. 2005. An Analysis of Ceramics from the Andrew's Place Site (1MB1), Southern Mobile County, Alabama. Master's thesis, Dept. of Anthropology and Sociology, University of Southern Mississippi, Hattiesburg.

Gardner, P. S. 1997. The Ecological Structure and Behavioral Implications of Mast Exploitation Strategies. In *People, Plants, and Landscapes: Studies in Paleoethnobotany,* ed. K. J. Gremillion, 161–78. Tuscaloosa: University of Alabama Press.

Garrard, A. 1999. Charting the Emergence of Cereal and Pulse Domestication in Southwest Asia. *Environmental Archaeology* 4: 57–76.

Geiger, E., and G. Borgstrom. 1962. Fish Protein—Nutritive Aspects. In *Fish as Food,* vol. 2, *Nutrition, Sanitation, and Utilization,* ed. G. Borgstrom, 29–114. London: Academic Press.

Geisen, M. J. 1992. Late Prehistoric Populations in the Ohio Area: Biological Affinities and Stress Indicators. Ph.D. dissertation, Ohio State University, Columbus.

Gemines. 1980. *Geografía de Chile a Color,* pp. 122–25. Santiago, Chile: Editorial Antártica.

———. 1982. *Geografía Económica de Chile.* Santiago, Chile: Editorial Andrés Bello.

Gietzen, D. W. 1993. Neural Mechanisms in the Responses to Amino Acid Deficiency. *Journal of Nutrition* 123: 610–25.

Gietzen, D. W., L. H. McArthur, J. C. Theisen, and Q. R. Rogers. 1992. Learned Preference for the Limiting Amino Acid in Rats Fed a Threonine-Deficient Diet. *Physiology and Behavior* 51: 909–14.

Giscard, P. H. 2001. Pratiques funeraires des Hunnu. Travuax de la Mission Archaeologique Francaise en Mongolie realizes Durant le campagnes de 1998 and 1999 dans la necropole Hunnu de'Egiin Gol. Eurasiat.

Glover, I. C. 1977. The Hoabinhian: Hunter-Gatherers or Early Agriculturalists in South-East Asia? In *Hunter-Gatherers and First Farmers beyond Europe,* ed. J. V. S. Megaw, 145–66. Leicester, U.K.: Leicester University Press.

Glover, I. C., and C. F. W. Higham. 1996. New Evidence for Early Rice Cultivation in South, Southeast and East Asia. In *The Origins and Spread of Agriculture and Pastoralism in Eurasia,* ed. D. R. Harris, 413–41. Washington, D.C.: Smithsonian Institution Press.

Gong, Q. 1988. New Excavations and Research in Shaanxi. *Kaogu yu Wenwu* 5–6: 41–52.

Goodman, A. H. 1993. On the Interpretation of Health from Skeletal Remains. *Current Anthropology* 34 (3): 381–88.

———. 1998. The Biological Consequences of Inequality in Antiquity. In *Building a New Biocultural Synthesis: Political and Economic Perspectives on Human Biology,* ed. A. H. Goodman and T. L. Leatherman, 147–64. Ann Arbor: University of Michigan Press.

Goodman, A. H., and G. J. Armelagos. 1989. Infant and Childhood Morbidity and Mortality Risks in Archaeological Populations. *World Archaeology* 21: 225–43.

Goodman, A. H., G. J. Armelagos, and J. C. Rose. 1980. Enamel Hypoplasias as Indicators of Stress in Three Prehistoric Populations from Illinois. *Human Biology* 52: 515–28.

Goodman, A. H., and L. Carpasso. 1992. Recent Contributions to the Study of Enamel Developmental Defects. *Journal of Paleopathology* Monographic Publication 2. Chieti, Italy.

Goodman, A. H., J. Lallo, G. J. Armelagos, and J. C. Rose. 1984. Health Changes at Dickson Mounds, Illinois, AD 950–1300. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 271–304. Orlando, Fla.: Academic Press.

Goodman, A. H., and D. L. Martin. 2002. Reconstructing Health Profiles from Skeletal Remains. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 11–60. Cambridge, U.K.: Cambridge University Press.

Goodman, A. H., D. L. Martin, and G. J. Armelagos. 1984. Indications of Stress from Bone and Teeth. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 13–39. Orlando, Fla.: Academic Press.

Goodman, A. H., D. L. Martin, C. P. Klein, M. S. Peele, N. A. Cruse, L. R. McEwen, A. Saeed, and B. M. Robinson. 1992. Cluster Bands, Wilson Bands and Pit Patches: Histological and Enamel Surface Indicators of Stress in the Black Mesa Anasazi Population. In Recent Contributions to the Study of Enamel Developmental Defects, ed. A. H. Goodman and L. L. Capasso, 115–27. *Journal of Paleopathology* Monographic Publications 2. Chieti, Italy.

Goodman, A. H., C. Martinez, and A. Chavez. 1991. Nutritional Supplementation and the Development of LEH in Children from Tezonteopan, Mexico. *American Journal of Clinical Nutrition* 53: 773–81.

Goodman, A. H., G. Pelto, and L. H. Allen. 1992. Socioeconomic and Anthropometric Correlates of Linear Enamel Hypoplasia in Children from Solis, Mexico. In Recent Contributions to the Study of Enamel Developmental Defects, ed. A. H. Goodman and L. Carpasso, 373–80. *Journal of Paleopathology* Monographic Publications 2. Chieti, Italy.

Goodman, A. H., and J. C. Rose. 1990. Assessment of Systemic Physiological Perturbations from Dental Enamel Hypoplasias and Associated Histological Structures. *Yearbook of Physical Anthropology* 33: 59–110.

———. 1991. Dental Enamel Hypoplasias as Indicators of Nutritional Stress. In *Advances in Dental Anthropology,* ed. M. A. Kelley and C. S. Larsen, 279–93. New York: Wiley-Liss.

Goring-Morris, N., and A. Belfer-Cohen. 1998. The Articulation of Cultural Processes and Late Quaternary Environmental Changes in Cisjordan. *Paléorient* 23: 71–93.

Gorman, C. F. 1971. The Hoabinhian and After: Subsistence Patterns in Southeast Asia during the Late Pleistocene and Early Recent Periods. *World Archaeology* 2: 300–320.

Gorman, C. F., and P. Charoenwongsa. 1976. Ban Chiang: A Mosaic of Impressions from the First Two Years. *Expedition* 18 (4): 14–26.

Grauer, A., and P. Stuart-Macadam, eds. 1998. *Sex and Gender in Paleopathological Perspective.* Cambridge, U.K.: Cambridge University Press.

Gravlee, C. C., H. R. Bernard, and W. R. Leonard. 2003. Heredity, Environment, and Cranial Form: A Reanalysis of Boas's Immigrant Data. *American Anthropologist* 105: 125–38.

Greenblatt, C., and M. Spigelman. 2003. *Emerging Pathogens.* New York: Oxford University Press.

Greenfield, G. B. 1969. *Radiology of Bone Diseases.* Philadelphia: Lippincott.

Grieder, T., A. M. Bueno, C. E. Smith Jr., and R. M. Malina. 1988. *La Galgada, Peru: A Preceramic Culture in Transition.* Austin: University of Texas Press.

Grist, D. H. 1986. *Rice.* London: Longman.

Groube, L. 1996. The Impact of Diseases upon the Emergence of Agriculture. In *The Origins and Spread of Agriculture and Pastoralism in Eurasia,* ed. D. R. Harris, 101–28. London: UCL Press.

Grupe, G. 1995. Etiology of the Cribra Orbitalia: Effect of Amino Acid Profile in Bone Collagen and the Iron Content of Bone Minerals. *Zeitschrift fur morphologie and Anthropologie* 81: 125–37.

Grupe, G., and H. Schutkowski. 1989. Dietary Shift during the Second Millennium BC in Prehistoric Shimal, Oman Peninsula. *Paléorient* 15 (2): 77–84.

Guillén, S. E. 1992. The Chinchorro Culture: Mummies and Crania in the Reconstruction of Preceramic Coastal Adaptation in the South Central Andes. Ph.D. dissertation, University of Michigan, Ann Arbor.

Haas, J., W. Creamer, and A. Ruiz. 2004. Dating the Late Archaic Occupation of the Norte Chico Region in Peru. *Nature* 432: 1020–23.

Haber, A., and T. Dayan. 2004. Analyzing the Process of Domestication: Hagoshrim as a Case Study. *Journal of Archaeological Science* 31: 1587–1601.

Haduch, E. 2002. The Human Biology of the Neolithic and Bronze Age Population of Poland. In *Ecological Aspects of Past Human Settlements in Europe,* ed. P. Bennike, E. B. Bodzsar, and C. Susanne, 143–57. Budapest: Eotvos University Press.

Hall, S. 1990. Hunter-Gatherer-Fishers of the Fish River Basin: A Contribution to the

Holocene Prehistory of the Eastern Cape. Ph.D. dissertation, University of Stellenbosch, Stellenbosch, South Africa.

Hallberg, L., M. Hoppe, M. Andersson, and L. Hulthén. 2003. The Role of Meat to Improve the Critical Iron Balance during Weaning. *Pediatrics* 111: 864–70.

Hallberg, L., and L. Hulthén. 2000. Vitamins, Minerals, and Phytochemicals, Prediction of Dietary Iron Absorption: An Algorithm for Calculating Absorption and Bioavailability of Dietary Iron. *American Journal of Clinical Nutrition* 71: 1147–60.

Hally, D. J. 1994. An Overview of Lamar Culture. In *Ocmulgee Archaeology, 1936–1986,* ed. D. J. Hally, 144–221. Athens: University of Georgia Press.

Hally, D. J., and J. B. Langford. 1988. *Mississippi Period Archaeology of the Georgia Valley and Ridge Province.* University of Georgia Laboratory of Archaeology Series, Report 25, Athens.

Hally, D. J., and J. L. Rudolph. 1986. *Mississippi Period Archaeology of the Georgia Piedmont.* University of Georgia Laboratory of Archaeology Series, Report 24, Athens.

Hamlin, C. 1998. Labor Divisions in an Early Archaic Florida Population: The Archaeological Evidence for Gender Roles at the Windover Site (8BR246). Unpublished master's thesis, Florida State University, Tallahassee.

Hammond, N., ed. 1991. *Cuello: An Early Maya Community in Belize.* Cambridge, U.K.: Cambridge University Press.

Handsuren, Ts. 1969. *Jujanii aj baidal, soyal, zan Zanshiliin tuhai* (The custom, culture and life style of the Jujan Population The Study of History). Tuukhiin Sudlal VIII. N-VIII. Ulaanbaatar: Printing House Education.

Hansen, U. L., O. V. Nielsen, and V. Alexandersen. 1972. A Mesolithic Grave from Melby in Zealand, Denmark. *Acta Archaeologica* 43: 239–49.

Hanson, A. J., and D. W. Steadman. 2001. The Frequency of Tuberculosis and Treponematosis in a New Middle Mississippian Sample from Central Illinois. *American Journal of Physical Anthropology* supplement 32: 75.

Harding, R. M., F. W. Rösing, and R. R. Sokal. 1989. Cranial Measurements Do Not Support Neolithization of Europe by Demic Expansion. *Homo* 40 (1–2): 45–57.

Harper, A. E., N. J. Benevenga, and R. M. Wohlhueter. 1970. Effects of Ingestion of Disproportionate Amounts of Amino Acids. *Physiology Revue* 50: 428–558.

Harris, D. R. 1989. An Evolutionary Continuum of People-Plant Interaction. In *Foraging and Farming: The Evolution of Plant Exploitation,* ed. D. R. Harris and G. C. Hillman, 11–26. London: Unwin Hyman.

Harris, E. F., R. H. Potter, and J. Lin. 2001. Secular Trend in Tooth Size in Urban Chinese Assessed from Two-Generation Family Data. *American Journal of Physical Anthropology* 115: 312–18.

Harrisson, B. 1967. A Classification of Stone Age Burials from Niah Great Cave, Sarawak. *Sarawak Museum Journal* 15: 126–200.

Harrisson, T. 1 957. The Great Cave of Niah: A Preliminary Report on Bornean Prehistory. *Man* 57: 161–66.

———. 1959. New Archaeological and Ethnological Results from Niah Caves, Sarawak. *Man* 59: 1–8.

———. 1972. The Prehistory of Borneo. *Asian Perspectives* 13: 17–45.

Hart, S., B. T. Arriaza, and V. G. Standen. 1998. A Comparison of Porotic Hyperostosis and Cribra Orbitalia between the Fishing and Agricultural Populations in Northern Chile. In *Resumenes III Congreso Mundial de Estudios sobre Momias,* 17–18. Arica, Chile: Universidad de Tarapacá, Departamento de Arqueología y Museología.

Haselgrove, C. 1999. The Iron Age. In *The Archaeology of Britain: An Introduction from the Upper Paleolithic to the Industrial Revolution,* ed. J. R. Hunter and I. Ralston, 113–34. London: Routledge.

Haswell-Elkins, M. R., and D. B. Elkins. 1996. Food-Borne Trematodes. In *Manson's Tropical Diseases,* ed. G. C. Cook, 1457–76. London: W. B. Saunders.

Hatch, J. W., and P. S. Willey. 1974. Stature and Status in Dallas Society. *Tennessee Archaeologist* 30: 108–31.

Hatch, J. W., P. S. Willey, and E. E. Hunt. 1983. Indicators of Status-Related Stress in Dallas Society: Transverse Lines and Cortical Thickness in Long Bones. *Midcontinental Journal of Archaeology* 8: 49–71.

Hauck, H. M., J. R. Hanks, and S. Subsaneh. 1959. Food Habits in a Siamese Village. *Journal of the American Dietetic Association* 35: 1143–48.

Headland, T. N. 1987. The Wild Yam Question: How Well Could Independent Hunter-Gatherers Live in a Tropical Rain Forest Ecosystem? *Human Ecology* 15: 463–91.

Headland, T. N., and L. A. Reid. 1989. Hunter-Gatherers and Their Neighbors from Prehistory to the Present. *Current Anthropology* 30: 43–66.

Heard-Bey, F. 1982. *From Trucial States to United Arab Emirates: A Society in Transition.* London: Longman.

Heaton, T. H. E. 1999. Spatial, Species, and Temporal Variations in the $^{13}C/^{12}C$ Ratios of C_3 Plants: Implications for Paleodiet Studies. *Journal of Archaeological Science* 26: 637–49.

Heckel, A. B. 1966. The Human Remains. In *Archaeological Excavation of the Womack Mounds (22YA1)*, ed. T. H. Koehler, 65–75. Bulletin No. 1. University of Mississippi: Mississippi Archaeological Association, University.

Hedman, K., E. A. Hargrave, and S. H. Ambrose. 2002. Inter- and Intra-site Comparisons of Mississippian Diet in the American Bottom: Results of Recent Stable Isotope Analyses of Bone Collagen and Apatite. *Midcontinental Journal of Archaeology* 27: 237–71.

Heilman, J., M. Martin Neely, and D. C. Cook. 1991. Trauma in Late Woodland Crania from Illinois. *Proceedings of the Indiana Academy of Science* 100 (1–2): 1–9.

Hellyer, P. 1998. *Hidden Riches: An Archaeological Introduction to the United Arab Emirates.* Abu Dhabi: Union National Bank.

Henan Institute of Cultural Relics and Archaeology. 1989. Preliminary report for the second through the sixth excavation at the Neolithic site of Jiahu in Wuyang, Henan.

———. 1991. Report on the Excavation at Meishan in Linru, Henan, in 1987–1988. *Huaxia Kaogu* 3: 5–23.

———. 2003. *Meng Zhuang.* Zhongzhou: Zhongzhou Publishing House of Ancient Books.

Herling, A. 1994. *Archaeological Research at Karannah and Saar, 1993.* Manama: Bahraini-German Excavations.

———. 1999. Necropoli and Burial Customs in the Tylos Era. In *Bahrain: The Civilisation of the Two Seas,* ed. Institut du Monde Arabe, 156–59. Ghent: Snoeck-Ducaju and Zoon.

Hershkovitz, I., and E. Galili. 1990. 8000-Year-Old Human Remains on the Sea Floor near Atlit Israel. *Human Evolution* 5: 319–46.

Hershkovitz, I., and A. Gopher. 1988. Human Remains from Horvat Galil, a Pre-Pottery Neolithic Site in the Upper Galilee, Israel. *Paléorient* 14: 119–23.

———. 1990. Paleodemography, Burial Customs and Food-Producing Economy at the Beginning of the Holocene: A Perspective from the Southern Levant. *Mitekufat Haeven/Journal of the Israel Prehistoric Society* 23: 9–47.

Hershkovitz, I., B. Ring, M. Speirs, E. Galili, M. Kislev, G. Edelson, and A. Hershkovitz. 1991. Possible Congenital Hemolytic Anemia in Prehistoric Coastal Inhabitants of Israel. *American Journal of Physical Anthropology* 85: 7–13.

Hershkovitz, I., M. Speirs, D. Frazer, D. Nadel, S. Wish-Baratz, and B. Arensburg. 1995. Ohalo H-2, a 19000 Year Old Skeleton from a Water Logged Site at the Sea of Galilee, Israel. *American Journal of Physical Anthropology* 96: 215–34.

Higham, C. 1989. *The Archaeology of Mainland Southeast Asia: From 10,000 BC to the Fall of the Angkor.* Cambridge, U.K.: Cambridge University Press.

———. 1994. Chronometric Hygiene and the Bronze Age of Southeast Asia. Paper presented at the 15th Meeting of the Indo-Pacific Prehistory Association, Chiang Mai, Thailand.

———. 1995. The Transition to Rice Cultivation in Southeast Asia. In *Last Hunters, First Farmers: New Perspectives on the Prehistoric Transition to Agricultur*e, ed. T. D. Price and A. B. Gebauer, 127–55. Sante Fe, N.Mex.: School of American Research Press.

———. 1996. *The Bronze Age and Southeast Asia.* Cambridge, U.K.: Cambridge University Press.

———. 2002. *Early Cultures of Mainland Southeast Asia.* Bangkok: River Books.

Higham, C., and R. Thosarat. 1998. *Prehistoric Thailand: From Early Settlement to Sukhotai.* Bangkok: River Books.

Hill, M. C. 1981. Analysis, Synthesis and Interpretation of Skeletal Material Excavated for the Gainesville Section of the Tennessee-Tombigbee Waterway. In *Biocultural Studies in the Gainesville Lake Area,* ed. G. M. Caddell, A. Woodrick, and M. C. Hill, 211–55. Office of Archaeological Research, Report of Investigations 14. Tuscaloosa: University of Alabama.

Hill, R. D. 1977. *Rice in Malaya.* Kuala Lumpur: Oxford University Press.

Hills, C. 1999. Early Historic Britain. In *The Archaeology of Britain: An Introduction from the Upper Palaeolithic to the Industrial Revolution,* ed. J. R. Hunter and L. Ralston, 176–93. London: Routledge.

Hillson, S. 1992. Dental Enamel Growth, Perikymata and Hypoplasia in Ancient Tooth Crowns. *Journal of the Royal Society of Medicine* 85: 460–66.

———. 1996. *Dental Anthropology.* Cambridge, U.K.: Cambridge University Press.

———. 2001. Recording Dental Caries in Archaeological Dental Remains. *International Journal of Osteoarchaeology* 11: 249–89.

Hinton, R. J. 1981. Temporomandibular Joint Size Adaptations in Prehistoric Indians. *Tennessee Archaeologist* 6: 89–111.

Hinton, R. J., M. O. Smith, and F. H. Smith. 1980. Tooth Size Changes in Prehistoric Tennessee Indians. *Human Biology* 52 (2): 229–45.

Hodges, D. 1987. Health and Agricultural Intensification in the Prehistoric Valley of Oaxaca, Mexico. *American Journal of Physical Anthropology* 73 (3): 323–32.

Hogue, S. H. 2000. Burial Practices, Mortality and Diet in East Central Mississippi: A Case Study from Oktibbeha County. *Southeastern Archaeology* 19: 63–81.

Hogue, S. H., and E. Peacock. 1995. Environmental and Osteological Analysis at the South Farm Site (22OK534), a Mississippian Farmstead in Oktibbeha Co, MS. *Southeastern Archaeology* 14: 31–45.

Højgaard, K. 1980. Dentition on Umm an-Nar (Trucial Oman), 2500 BC. *Scandinavian Journal of Dental Research* 88: 355–64.

Hojlund, F. 1989. Ethnic Composition of the Population of Dilmun. *Proceedings of the Seminar for Arabian Studies* 23: 1–8.

Holiday, D. M., S. Guillen, and D. J. Richardson. 2003. Diphyllobothriasis of the Chiribaya Culture 700–1476 AD of Southern Peru. *Comparative Parasitology* 70: 167–71.

Holloway, R. G. 2002. Pollen Analysis of Holocene Sediments. In *Windover: Multidisciplinary Investigations of an Early Archaic Florida Cemetery,* ed. G. H. Doran, 211–26. Gainesville: University Presses of Florida.

Holmer, U., and A. B. Maunsbach. 1956. Odontologische Untersuchungen von Zähnen und Kiefern des Menschen aus der Steinzeit. *Odontologisk Tidsskrift* 64: 437–521.

Hoppa, R. D. 2002. Paleodemography: Looking Back and Thinking Ahead. In *Paleodemography: Age Distributions from Skeletal Samples,* ed. R. D. Hoppa and J. W. Vaupel, 9–28. Cambridge, U.K.: Cambridge University Press.

Hoppa, R. D., and J. W. Vaupel. 2002. The Rostock Manifesto for Paleodemography: The Way from Stage to Age. In *Paleodemography: Age Distributions from Skeletal Samples,* ed. R. D. Hoppa and J. W. Vaupel, 1–8. Cambridge, U.K.: Cambridge University Press.

Horwitz, L. K. 2003. Temporal and Spatial Variation in Neolithic Caprine Exploitation Strategies: A Case Study of Fauna from the Site of Yiftah'el Israel. *Paléorient* 29: 19–58.

Horwitz, L. K., and P. Ducos. 2005. Counting Cattle: Trends in Neolithic *Bos frequencies* from the Southern Levant. *Revue de Paleobiologie, Geneve (*Special Edition in Honour of Louis Chaix) 10: 209–24.

Horwitz, L. K., and P. Smith. 2000. The Contribution of Animal Domestication to the Spread of Zoonoses: A Case Study from the Southern Levant. *Ibex, Journal of Mountain Ecology* 5: 77–84.

Horwitz, L. K., E. Tchernov, P. Ducos, C. Becker, A. von den Driesch, L. Martin, and A. Garrard. 1999. Animal Domestication in the Southern Levant. *Paléorient* 25: 63–80.

Howell, N. 1982. Village Composition Implied by a Paleodemographic Life Table: The Libben Site. *American Journal of Physical Anthropology* 59: 263–69.

Howells, W. W. 1989. *Skull Shapes and the Map: Craniometric Analyses in the Dispersion of Modern Humans.* Cambridge, Mass.: Peabody Museum of Archaeology and Ethnology, Harvard University.

Hrdlička, A. 1909. Tuberculosis among Certain Indian Tribes of the United States. *Bureau of American Ethnology Bulletin* 42: 1–48.

———. 1914. Anthropological Work in Peru, in 1913, with Notes on the Pathology of the Ancient Peruvians. *Smithsonian Miscellaneous Collections* 61 (18): 1–69.

———. 1932. Disease, Medicine and Surgery among the American Aborigines. *Journal of the American Medical Association* 94: 1661–66.

Hu, Yaowu. 2002. Palaeodietary Study and Some Relevant Problems. Ph.D. dissertation, University of Science and Technology of China, Hafei, Anhui.

Hu, Yaowu, Stanley H. Ambrose, and Changsui Wang. 2006. Stable Isotopic Analysis of Human Bones from Jiahu Site, Henan, China: Implications for the Transition to Agriculture. *Journal of Archaeological Science* 33: 1319–30.

Huang, S. 1982. Neolithic Crops in the Yellow River Valley. *Nongye Kaogu* 2: 434.

Huang, S., C. Wong, S. E. Antonarakis, T. Ro-Lien W. H. Y., Lo H. H., and H. H. Kazazian Jr. 1986. The Same "TATA" Box Beta-Thalassemia Mutation in Chinese and U.S. Blacks: Another Example of Independent Origins of Mutation. *Human Genetics* 74: 162–64.

Huang, S., X. Zhou, H. Zhu, Z. Ren, and Y. Zeng. 1990. Detection of Beta-thalassemia Mutations in the Chinese Using Amplified DNA from Dried Blood Specimens. *Human Genetics* 84: 129–31.

Huang, Y. 1996. Identification and Study of Faunal Remains from the Zhukaigou Site in Inner Mongolia. *Kaogu Xuebao* 4: 515–36.

Huffman, T. N. 1993. Broederstroom and the Central Cattle Pattern. *South Africa Journal of Science* 89: 220–26.

Hummel, S. 1988. Report on the Anthropological Activities during the 1988 Campaign at the Site of Shimal, Settlement SX, Tomb N, Ras al-Khaimah, U.A.E. Unpublished report, pp. 1–6. Ms. in possession of author.

Hutchinson, D. L. 1992. Comment on "The Osteological Paradox: Problems of Inferring Health from Skeletal Samples." *Current Anthropology* 33 (4): 360.

———. 2002. *Foraging, Farming, and Coastal Biocultural Adaptation in Late Prehistoric North Carolina.* Gainesville: University Press of Florida.

———. 2004. *Bioarchaeology of the Florida Gulf Coast: Continuity, Change, and Conflict.* Gainesville: University Press of Florida.

Hutchinson, D. L., and C. S. Larsen. 1988. Stress and Lifeway Change: The Evidence from Enamel Hypoplasia. In *The Archaeology of Mission Santa Catalina de Guale,* vol. 2, *Biocultural Interpretations of a Population in Transition,* ed. C. S. Larsen, 50–65. Anthropological Papers of the American Museum of Natural History 68. New York.

———. 2001. Enamel Hypoplasia and Stress in La Florida. In *Bioarchaeology of Spanish Florida: The Impact of Colonialism,* ed. C. S. Larsen, 181–206. Gainesville: University Press of Florida.

Hutchinson, D. L., C. S. Larsen, L. Norr, and M. J. Schoeninger. 2000. Agricultural Melodies and Alternative Harmonies in Florida and Georgia. In *Bioarchaeological Studies of Life in the Age of Agriculture: A View from the Southeast,* ed. P. M. Lambert, 96–115. Tuscaloosa: University of Alabama Press.

Hutchinson, D. L., C. S. Larsen, M. J. Schoeninger, and L. Norr. 1998. Regional Variation in the Pattern of Maize Adoption and Use in Florida and Georgia. *American Antiquity* 63: 397–416.

Hutchinson, D. L., C. S. Larsen, M. A. Williamson, V. D. Green Clow, and M. L. Powell. 2005. Temporal and Spatial Variation in the Patterns of Treponematosis in Georgia and Florida. In *The Natural History of Syphilis,* ed. M. L. Powell and D. C. Cook. Gainesville: University Press of Florida.

Hutterer, K. L. 1983. The Natural and Cultural History of Southeast Asian Agriculture. *Anthropos* 78: 169–212.

Iacono, N., L. Weeks, and K. Davis. 1996. The Settlement Areas A–D. In *Excavations at Al Sufouh: A Third Millennium Site in the Emirate of Dubai,* ed. J. N. Benton, 24–33. Brepols: Abiel.

Ishikawa, Y. 2000. Niacin Deficiency Disease Pellagra. *Ryoikibetsu Shokogun Shirizu* 29: 91–93. (In Japanese.)

Jackes, M. 1992. Paleodemography: Problems and Techniques. In *Skeletal Biology of*

Past Peoples, ed. S. R. Saunders and M. A. Katzenberg, 189–224. New York: Wiley Liss.

———. 1994. Birth Rates and Bones. In *Strength in Diversity: A Reader in Physical Anthropology,* ed. A. Herring and L. Chan, 155–85. Toronto: Canadian Scholars' Press.

———. 2004. Osteological Evidence for Mesolithic and Neolothic Violence: Problems of Interpretation. In *Violent Interactions in the Mesolithic: Evidence and Meaning*, ed. M. Roksandic, 23–39. Oxford: BAR International Series 1237.

Jackes, M., D. Lubell, and C. Meiklejohn. 1997. Healthy but Mortal: Human Biology and the First Farmers of Western Europe. *Antiquity* 71: 639–58.

Jacobi, K. P. 1997. The Human Remains from the Perry Site (1LU25), Alabama. Ms. on file, Department of Anthropology, University of Alabama, Tuscaloosa.

———. 2000. An Analysis of the Prehistoric Skeletal Remains Recovered at Kogers Island, Northern Alabama. Ms. on file, Department of Anthropology, University of Alabama, Tuscaloosa.

Jacobi, K. P., and M. E. Danforth. 2002. Analysis of Interobserver Scoring Patterns in Porotic Hyperostosis and Cribra Orbitalia. *International Journal of Osteoarchaeology* 3: 297–302.

Jacobi, K. P., M. E. Danforth, and G. D. Wrobel. 2004. Funked up and Yowza! An Analysis of Terms Used in Description of Scoring of Periosteal Lesions. Paper presented at the Annual Meeting of the American Association of Physical Anthropology, Tampa.

Jantz, R. L. 1995. Special Issue on the Population Biology of Late Nineteenth-Century Native North Americans and Siberians: Analyses of Boas's Data. *Human Biology* 67: 335–516.

Jenike, M. R. 2001. Nutritional Ecology: Diet, Physical Activity and Body Size. In *Hunter-Gatherers: An Interdisciplinary Perspective,* ed. C. Panter-Brick, R. H. Layton, and P. Rowley-Conwy, 205–38. Cambridge, U.K.: Cambridge University Press.

Jenkins, N. J. 1982. *Archaeology of the Gainesville Lake Area: Synthesis.* Office of Archaeological Research, Report of Investigations 23. Tuscaloosa: University of Alabama.

Jensen, J. 2001. *Danmarks Oldtid.* Copenhagen: Gyldendal.

Jerardino-Wiesenborn, A. M. S. 1996. Changing Social Landscapes of the Western Cape Coast of Southern Africa over the Last 4500 Years. Ph.D. dissertation, University of Cape Town, Cape Town, South Africa.

Joerschke, B. C. 1983. The Demography, Long Bone Growth, and Pathology of a Middle Archaic Skeletal Population from Middle Tennessee: The Anderson Site (40WM9). M.A. thesis, Department of Anthropology, University of Tennessee, Knoxville.

Jones, M. E. 1996. *The End of Roman Britain.* Ithaca, N.Y.: Cornell University Press.

Juliano, B. O. 1993. *Rice in Human Nutrition.* Rome: Food and Agriculture Organization.

Jurmain, R. D. 1991. Paleoepidemiology of Trauma in a Prehistoric Central California Population. In *Human Paleopathology: Current Syntheses and Future Options*, ed. D.J. Ortner and A.C. Aufderheide, 241–50. Washington D.C.: Smithsonian Institution Press.

Kamalanathan, G. S., H. M. Hauck, and C. Kittiveja. 1960. Dental Development of Children in a Siamese Village, Bank Chan, 1953. *Journal of Dental Research* 39: 455–61.

Katzenberg, M. A. 1992. Changing Diet and Health in Pre- and Protohistoric Ontario. In *Health and Lifestyle Change,* ed. R. Huss-Ashmore, J. Schall, and M. Hediger, 23–31. Museum of Applied Science, Center for Archaeology, Research Papers in Science and Archaeology 9. Philadelphia: University of Pennsylvania.

Katzenberg, M. A., and S. R. Saunders. 2000. *Biological Anthropology of the Human Skeleton.* New York: Wiley Liss.

Kealhofer, L. 1996. The Human Environment during the Terminal Pleistocene and Holocene in Northeastern Thailand: Phytolith Evidence from Lake Kumphawapi. *Asian Perspectives* 35 (2): 227–54.

———. 2002. Changing Perceptions of Risk: The Development of Agro-Ecosystems in Southeast Asia. *American Anthropologist* 104 (1): 178–94.

———. 2003. Looking into the Gap: Land Use and the Tropical Forests of South Thailand. *Journal of Archaeological Science* 30 (2): 185–94.

Keller, C. 1946. *El Departamento de Arica.* Santiago, Chile: Ministerio de Economía y Comercio.

Kelley, M. A., and L. E. Eisenberg. 1987. Blastomycosis and Tuberculosis in Early American Indians: A Biocultural View. *Midcontinental Journal of Archaeology* 12 (1): 89–116.

Kelley, M. A., and C. S. Larsen, eds. 1991. *Advances in Dental Anthropology.* New York: Wiley Liss.

Kelly, R. L. 1995. *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways.* Washington, D.C.: Smithsonian Institution Press.

Kemkes-Grottenthaler, A. 2005. The Short Die Young: The Interrelationship between Stature and Longevity—Evidence from Skeletal Remains. *American Journal of Physical Anthropology* (online).

Kennedy, K. A. R. 1984. Growth, Nutrition, and Pathology in Changing Paleodemographic Settings in South Asia. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 169–92. Orlando, Fla.: Academic Press.

Kent, S. 1986. The Influence of Sedentism and Aggregation on Porotic Hyperostosis and Anaemia: A Case Study. *Man* 21 (3): 605–36.

Kerdpon, D., and S. Sirirungrojying. 1999. A Clinical Study of Oral Tori in Southern Thailand: Prevalence and the Relation to Parafunctional Activity. *European Journal of Oral Science* 107: 9–13.

Kervran, M. 1990. Necropoles islamique anciennes a Qal át al-Bahrain. Paper presented at Anthropologique et Archeologie Funerairers sur la Rive Arabe du Golfe, 2er–1er millenaires av. J.C., CNRS, Lyons, April.

Kieser, J. A. 1990. *Human Adult Odontometrics.* Cambridge, U.K.: Cambridge University Press.

Kiesewetter, H. 1996. Graveyard and Human Remains. Unpublished report, pp. 1–14. Ms. in possession of author.

———. 2003. The Neolithic Population at Jebel Buhais 18: Remarks on Funerary Practices, Palaeodemography and Palaeopathology. In *Archaeology of the United Arab Emirates—Proceedings of the First International Conference on the Archaeology of the U.A.E.,* ed. D. Potts, H. Al Naboodah, and P. Hellyer, 36–43. London: Trident Press.

Kilgore, L., R. D. Jurmain, and D. Van Gerven. 1997. Palaeoepidemiological Patterns of Trauma in a Medieval Nubian Skeletal Population. *International Journal of Osteoarchaeology* 7: 1103–14.

King, A. 2003. *Etowah: The Political History of a Chiefdom Capital.* Tuscaloosa: University of Alabama Press.

Kiple, K. 2000. The Question of Palaeolithic Nutrition and Modern Health: From the End to the Beginning. In *The Cambridge World History of Food,* ed. K. Kiple and K. C. Ornelas, 1704–9. Cambridge, U.K.: Cambridge University Press.

Kiple, K., and K. C. Ornelas, ed. 2000. *The Cambridge World History of Food.* Cambridge, U.K.: Cambridge University Press.

Kirveskari, P., H. Hansson, B. Hedegard, and U. Karlsson. 1978. Crown Size and Hypodontia in the Permanent Dentition of Modern Skolt Lapps. *American Journal of Physical Anthropology* 48: 107–12.

Klopstook, A. 1939. Typhus, Typhoid and Paratyphoid in Palestine. *Medical Leaves* 2: 83–90.

Knight, V. J. 1984. Late Prehistoric Adaptation in the Mobile Bay Region. In *Perspectives on Gulf Coast Prehistory,* ed. D. D. Davis, 198–215. Gainesville: University Press of Florida.

Koch, E. 1998. *Neolithic Bog Pots from Zealand, Møn, Lolland and Falster.* Nordiske Fortidsminder 16, Series B. Copenhagen.

Koch, P. L., M. L. Fogel, and N. Tuross. 1994. Tracing the Diets of Fossil Animals Using Stable Isotopes. In *Stable Isotopes in Ecology and Environmental Science,* ed. K. Lajtha and R. H. Michener, 63–92. Oxford: Blackwell Scientific Publications.

Konigsberg, L. W. 1988. Migration Models of Prehistoric Postmarital Residence. *American Journal of Physical Anthropology* 77: 471–82.

———. 1990a. Temporal Aspects of Biological Distance: Serial Correlation and Trend in a Prehistoric Skeletal Lineage. *American Journal of Physical Anthropology* 82 (1): 45–52.

———. 1990b. Analysis of Prehistoric Biological Variation under a Model of Isolation by Geographic and Temporal Distance. *Human Biology* 62 (1): 49–70.

Konigsberg, L. W., and J. E. Buikstra. 1995. Regional Approaches to the Investigation of Past Human Biocultural Structure. In *Regional Approaches to Mortuary Analysis,* ed. L. A. Beck, 191–219. New York: Plenum Press.

Konigsberg, L. W., and S. R. Frankenberg. 2002. Deconstructing Death in Paleodemography. *American Journal of Physical Anthropology* 117: 297–309.

Krenzer, U. 1996. Anthropologischer Beitrag zur mesolithisch-neolithischen Transition. *Homo* 47: 223–47.

Krigbaum, J. 2001. *Human Paleodiet in Tropical Southeast Asia: Isotopic Evidence from Niah Cave and Gua Cha.* New York: New York University Press.

———. 2003. Neolithic Subsistence Patterns in Northern Borneo Reconstructed with Stable Carbon Isotopes of Enamel. *Journal of Anthropological Archaeology* 22: 292–304.

———. 2005. Reconstructing Human Subsistence in the West Mouth, Niah Cave, Sarawak Burial Series Using Stable Isotopes of Carbon. *Asian Perspectives* 44: 73–89.

Krueger, H. W., and C. H. Sullivan. 1984. Models for Carbon Isotope Fractionation between Diet and Bone. In *Stable Isotopes in Nutrition,* ed. J. R. Turnlund and P. E. Johnson, 205–22. Symposium Series 258. Washington, D.C.: American Chemical Society.

Kuchikura, Y. 1993. Wild Yams in the Tropical Rain Forest: Abundance and Dependence among the Semaq Beri of Peninsular Malaysia. *Man and Culture in Oceania* 9: 81–102.

Kuijt, I. 2000. People and Space in Early Agricultural Villages: Exploring Daily Lives, Community Size and Architecture in the Late Pre-Pottery Neolithic. *Journal of Anthropological Archaeology* 19: 75–102.

Kuijt, I., and N. Goring-Morris. 2002. Foraging, Farming and Social Complexity in the Pre-Pottery Neolithic of the Southern Levant: A Review and Synthesis. *Journal of World Prehistory* 16: 361–440.

Kull, U. 1990. *Evolution des Menschen: Biologische, Soziale und Kulturelle Evolution.* Stuttgart: J. B. Metzler.

Kunter, M. 1981. Bronze- und Eisenzeitliche Skelettfunde aus Oman: Bemerkungen zur Bevlkerungsgeschichte Ostarabiens. (Skeletal Remains Dating from the Bronze and Iron Ages in Oman: Commentaries on the History of Population in Eastern Arabia.) *Homo* 32: 197–210. English translation by E. J. Blau; ms. in possession of author.

———. 1983. Chronologische und Regionale Unterschiede bei Pathologischen Zahnbefunden auf der Arabischen Halbinsel. (Chronological and Regional Differences Found in Pathological Tooth Remains from the Arabian Peninsula.) *Archäologisches Korrespondenzblatt* 13 (3): 339–43. English translation by E. J. Blau; ms. in possession of author.

———. 1991. Die Menschlichen Skelettreste aus den Gräbern von Umm an-Nar, Abu Dhabi, U.A.E.: 3 Jt. v. Chr. (The Human Skeletal Remains from the Graves of Umm an-Nar, Abu Dhabi, U.A.E., 3rd Millennium BC). In *The Island of Umm an-Nar,* vol. 1, *Third Millennium Graves,* ed. K. Frifelt, 163–79. Munksgaard: Jutland Archaeological Society Publications. English translation by D. T. Potts; ms. in possession of author.

Kurth, G., and O. Röhrer-Ertl. 1981. On the Anthropology of the Mesolithic to Chalcolithic Human Remains from the Tell es-Sultan in Jericho, Jordan. In *Excavations at Jericho,* vol. 3, ed. K. M. Kenyon, 407–99. Jerusalem: British School of Archaeology.

Lahr, M. M. 1996. *The Evolution of Modern Human Diversity.* Cambridge, U.K.: Cambrige University Press.

Lahren, C. H., and H. Berryman. 1984. Fracture Patterns and Status at Chucalissa (40SY1): A Biocultural Approach. *Tennessee Archaeologist* 9: 15–21.

Lallo, J., G. J. Armelagos, and J. C. Rose. 1978. Paleoepidemiology of Infectious Disease in the Dickson Mounds Populations. *Medical College of Virginia Quarterly* 14: 17–23.

Lalueza-Fox, C., and A. Gonzalez-Martin. 1999. Oral Pathology on the Iberian Peninsula and Balearic Islands from the Mesolithic to the Present Time. *Homo* 50 (1): 54–65.

Lamb, H. H. 1995. *Climate History and the Modern World.* London: Methuen.

Lambert, P. M. 1993. Health in Prehistoric Populations of the Santa Barbara Channel Islands. *American Antiquity* 58 (3): 509–22.

———, ed. 2000. *Bioarchaeological Studies of Life in the Age of Agriculture.* Tuscaloosa: University of Alabama Press.

Lanning, E. P. 1967. Perú before the Incas. Englewood Cliffs, N.J.: Prentice-Hall.

Larsen, C. E. 1983. *Holocene Land Use on the Bahrain Islands.* Chicago: University of Chicago Press.

———. 1986. Variation in Holocene Land Use Patterns on the Bahrain Islands: Construction of a Land Use Model. In *Bahrain through the Ages: The Archaeology,* ed. H. Al-Khalifa and M. Rice, 25–46. London: KPI.

Larsen, C. S. 1981. An Analysis of Skeletal Materials from Tibbee Creek. In *Archaeological Salvage Excavations at the Tibbee Creek Site, Lowndes County, Mississippi,* ed. J. W. O'Hear, C. S. Larsen, M. M. Scarry, J. Phillips, and E. Simons. Report submitted to the U.S. Army Corps of Engineers, Mobile District.

———. 1982. *The Anthropology of St. Catherine's Island,* vol. 3, *Prehistoric Human Biological Adaptation.* Anthropological Papers of the American Museum of Natural History 57, part 3. New York.

———. 1983. Behavioural Implications of Temporal Change in Cariogenesis. *Journal of Archaeological Science* 10: 1–8.

———. 1984. Health and Disease in Prehistoric Georgia: The Transition to Agriculture. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 307–38. Orlando, Fla.: Academic Press.

———. 1990. *The Archaeology of Mission Santa Catalina de Guale,* vol. 2, *Biocultural Interpretations of a Population in Transition*, ed. Clark S. Larsen, 3–150. Anthropological Papers of the American Museum of Natural History, 68. New York.

———. 1995. Biological Changes in Human Populations with Agriculture. *Annual Review of Anthropology* 24: 185–235.

———. 1997. *Bioarchaeology: Interpreting Behavior from the Human Skeleton.* Cambridge, U.K.: Cambridge University Press.

———. 1998. Gender, Health and Activity in Foragers and Farmers in the American Southeast: Implications for Social Organization in the Georgia Bight. In *Sex and Gender in Paleopathological Perspective,* ed. A. Grauer and P. Stuart-Macadam, 165–87. Cambridge, U.K.: Cambridge University Press.

———. 2000. Dietary Reconstruction and Nutritional Assessment of Past Peoples. In *The Cambridge World History of Food,* ed. K. Kiple and K. C. Ornelas, 13–33. Cambridge, U.K.: Cambridge University Press.

———. 2002a. Bioarchaeology: The Lives and Lifestyles of Past People. *Journal of Archaeological Research* 10: 119–66.

———. 2002b. *The Bioarchaeology of Late Prehistoric Guale.* Anthropological Papers of the American Museum of Natural History 84. New York.

Larsen, C. S., A. W. Crosby, M. C. Griffin, D. L. Hutchinson, C. B. Ruff, K. F. Russell, M. J. Schoeninger, and others. 2002. A Biohistory of Health and Behavior in the Georgia Bight: The Agricultural Transition and the Impact of European Contact. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 406–39. Cambridge, U.K.: Cambridge University Press.

Larsen, C. S., M. C. Griffin, D. L. Hutchinson, V. E. Noble, L. Norr, R. F. Pastor, C. B. Ruff, and others. 2001. Frontiers of Contact: Bioarchaeology of Spanish Florida. *Journal of World Prehistory* 15: 69–123.

Larsen, C. S., and D. E. Harn. 1994. Health in Transition in the Georgia Bight. In *Paleonutrition: The Diet and Health of Prehistoric Americans*, ed. K. D. Sobolik, 222–34. Carbondale: Southern Illinois University Press. Occasional Paper Series, 22.

Larsen, C. S., D. L. Hutchinson, M. J. Schoeninger, and L. Norr. 2001. Food and Stable Isotopes in La Florida: Diet and Nutrition before and after Contact. In *Bioarchaeology of Spanish Florida: The Impact of Colonialism,* ed. C. S. Larsen, 52–81. Gainesville: University Press of Florida.

Larsen, C. S., and R. L. Kelly, eds. 1995. *Bioarchaeology of the Stillwater Marsh: Prehistoric Human Adaptation in the Western Great Basin.* New York: American Museum of Natural History.

Larsen, C. S., and G. R. Milner. 1994. *In the Wake of Contact.* New York: Wiley-Liss.

Larsen, C. S., and C. B. Ruff. 1994. The Stresses of Conquest in Spanish Florida: Structural Adaptation and Change before and after Contact. In *In the Wake of Contact: Biological Responses to Conquest,* ed. C. S. Larsen and G. R. Milner, 21–34. New York: Wiley-Liss.

Larsen, C. S., C. B. Ruff, and M. C. Griffin. 1996. Implications of Changing Biomechanical and Nutritional Environments for Activity and Lifeway in the Eastern Spanish Borderlands. In *Bioarchaeology of Native American Adaptation in the Spanish Borderlands,* ed. B. J. Baker and L. Kealhofer, 95–125. Gainesville: University Press of Florida.

Larsen, C. S., C. B. Ruff, and R. L. Kelly. 1995. Structural Analysis of the Stillwater Postcranial Human Remains: Behavioral Implications of Articular Pathology and Long Bone Diaphyseal Morphology. In *Bioarchaeology of the Stillwater Marsh: Prehistoric Human Adaptation in the Western Great Basin,* ed. C. S. Larsen and R. L. Kelly, 107–33. New York: American Museum of Natural History.

Larsen, C. S., R. Shavit, and M. C. Griffin. 1991. Dental Caries Evidence for Dietary Change: An Archaeological Context. In *Advances in Dental Anthropology,* ed. M. A. Kelley and C. S Larsen, 179–202. New York: Wiley-Liss.

Larsson, L. 1990. The Mesolithic of Southern Scandinavia. *Journal of World Prehistory* 4 (3): 257–309.

Layrisse, M., C. Martinez-Torres, and M. Roche. 1968. The Effect of Various Foods on Iron Absorption. *American Journal of Clinical Nutrition* 21: 1175–83.

Lazenby, R. A., and P. McCormack. 1985. Salmon and Malnutrition on the Northwest Coast. *Current Anthropology* 26 (3): 379–84.

Lee, R. B., and M. Biesele. 2002. Local Cultures and Global Systems: The Ju/'hoansi-!Kung and Their Ethnographers Fifty Years On. In *Chronicling Cultures: Long-Term Field Research in Anthropology,* ed. R. V. Kamper and A. P. Royce, 160–90. Walnut Creek, Calif.: Altamira Press.

Lee-Thorp, J. A., and N. J. van der Merwe. 1991. Aspects of the Chemistry of Modern and Fossil Biological Apatites. *Journal of Archaeological Science* 18: 343–54.

Lei, S., X. Yong-Yong, J. Xun, and D. Xiao-Han. 2006. Geographical Differences in Physiques of Male Youth of Age 18–20 Years in China. *American Journal of Human Biology* 18: 141–48.

Le Mort, F., I. Hershkovitz, and M. Spiers. 1994. Les restes Humains. In *Le site de Hatoula en judee occidentale, Israel,* ed. M. Lechevallier and A. Ronen, 59–72. Mémoires et Travaux du Centre de Recherches Préhistoriques Français de Jérusalem. Paris: Association Paléorient.

Lev-Yadun, S., A. Gopher, and S. Abbo. 2000. The Cradle of Agriculture. *Science* 288: 1602–1603.

Lewis, R. B. 1988. Fires on the Bayou: Cultural Adaptations in the Mississippi Sound Region. *Southeastern Archaeology* 7: 109–23.

Lewis, T. M. N., and M. Kneberg. 1961. *Eva, An Archaic Site.* Knoxville: University of Tennessee Press.

———. 1979. *Hiwassee Island: An Archaeological Account of Four Tennessee Indian Peoples.* Knoxville: University of Tennessee Press.

Liebermann, D. E. 1996. How and Why Humans Grow Thin Skulls: Experimental Evidence for Systematic Cortical Robusticity. *American Journal of Physical Anthropology* 101 (2): 217–36.

Lie Dan Lu T. 1999. *The Transition from Foraging to Farming and Origin of Agriculture in China.* BAR International Series 774. Oxford: British Archaeological Reports.

Lieverse, A. R. 1999. Diet and the Etiology of Dental Calculus. *International Journal of Osteoarchaeology* 9: 219–32.

Lillie, M. C. 1996. Mesolithic and Neolithic Populations of the Ukraine: Indications of Diet from Dental Pathology. *Current Anthropology* 47 (1): 135–41.

Littleton, J. 1998. *Skeletons and Social Composition: Bahrain 250 BC–250 AD.* Oxford, U.K.: Tempus Reparatum.

Littleton, J. In press. Ethnicity or Political Ecology: Making Sense of the Bahrain Bones. In *Intercultural Relations Between South and Southwest Asia. Studies in Commemoration of E.C.L. during Caspers (1934–1995)*, ed. E. Olijdam and R. Spoor. BAR International Series. Oxford, UK: Archaeopress.

Littleton, J., and B. Frohlich. 1989. An Analysis of Dental Pathology from Historic Bahrain. *Paléorient* 15: 59–75.

———. 1993. Fish-Eaters and Farmers: Dental Pathology in the Arabian Gulf. *American Journal of Physical Anthropology* 92: 427–47.

Liu, Li. 1994. Development of Chiefdom Societies in the Middle and Lower Yellow River Valley in Neolithic China: A Study of the Longshan Culture from the Perspective of Settlement Patterns. Ph.D. dissertation, Harvard University, Cambridge, Mass.

———. 1996. Settlement Patterns, Chiefdom Variability, and the Development of Early States in North China. *Journal of Anthropological Archaeology* 15: 237–88.

———. 2004. *The Chinese Neolithic: Trajectories of Early States.* Cambridge, U.K.: Cambridge University Press.

Liu, Zhiyi. 2000. Were "Rice Paddies" near Pengtoushan and Jiahu Sites? *Nongye Kaogu* 3: 70–72.

Livshits, G., and E. Kobyliansky. 1991. Fluctuating Asymmetry as a Possible Measure of Developmental Homeostasis in Humans: A Review. *Human Biology* 63: 441–66.

Lombard, P. 1999a. The Last Centuries of Dilmun. In *The Civilisation of the Two Seas,* ed. Institut du Monde Arabe, 130–44. Ghent: Snoeck-Ducaju and Zoon.

———. 1999b. The Occupation of Dilmun by the Kassites of Mesopotamia. In *The Civilisation of the Two Seas,* ed. Institute du Monde Arabe, 122–25. Ghent: Snoeck-Ducaju and Zoon.

Lopinot, N. H. 1994. A New Crop of Data on the Cahokia Polity. In *Agricultural Origins and Development in the Midcontinent,* ed. W. Green, 127–53. Office of the State Archaeologist, Report 19. Iowa City: University of Iowa.

Lovell, N. C. 1997. Trauma Analysis in Paleopathology. *American Journal of Physical Anthropology* 40: 139–70.

Lovell, N. C., and K. A. R. Kennedy. 1989. Society and Disease in Prehistoric South Asia. In *Old Populations and New Perspectives in the Archaeology of South Asia,* ed. M. Kenoyer, 89–92. Madison: University of Wisconsin Press.

Lovell, N. C., and I. Whyte. 1999. Patterns of Enamel Defects at Ancient Mendes, Egypt. *American Journal of Physical Anthropology* 110 (1): 69–80.

Lu, T. L. D. 1999. *The Transition from Foraging to Farming and the Origin of Agriculture in China.* BAR International Series 774: 1-233. Oxford: British Archaeological Reports.

Lubell, D., M. Jackes, H. Schwarcz, M. Knyf, and C. Meiklejohn. 1994. The Mesolithic-Neolithic Transition in Portugal: Isotopic and Dental Evidence of Diet. *Journal of Archaeological Science* 21: 201–16.

Lubell, D., M. Jackes, H. Schwarcz, and C. Meiklejohn. 1986. New Radiocarbon Dates for Moita do Sebastião. *Arqueologia* 14: 34–36.

Lukacs, J. R. 1981. Crown Dimensions of Deciduous Teeth from Prehistoric India. *American Journal of Physical Anthropology* 55 (2): 261–66.

———. 1985. Tooth Size Variation in Prehistoric India. *American Anthropologist* 87: 1–15.

———. 1987. Biological Relationships Derived from Morphology of Permanent Teeth: Recent Evidence from Prehistoric India. *Anthropologischer Anzeiger* 45 (2): 97–116.

———. 1989. Dental Paleopathology: Methods for Reconstructing Dietary Patterns. In *Reconstruction of Life from the Skeleton,* ed. M. Y. Iscan and K. A. R. Kennedy, 261–82. New York: Alan R. Liss.

———. 1992. Dental Paleopathology and Agricultural Intensification in South Asia: New Evidence from Bronze Age Harappa. *American Journal of Physical Anthropology* 87 (1): 133–50.

———. 1995. The "Caries Correction Factor": A New Method of Calibrating Dental Caries Rates to Compensate for Antemortem Loss of Teeth. *International Journal of Osteoarchaeology* 5: 151–56.

———. 1996. Sex Differences in Dental Caries Rates with the Origin of Agriculture in South Asia. *Current Anthropology* 37: 147–53.

———. 1999. Interproximal Contact Hypoplasia in Primary Teeth: A New Enamel Defect with Clinical and Anthropological Relevance. *American Journal of Human Biology* 11: 718–24.

———. 2007. Interpreting Biological Diversity in South Asian Prehistory: Early Holocene Population Affinities and Subsistence Adaptations. In *The Evolution and Diversity of Humans in South Asia,* ed. Michael D. Petraglia, 271–96. Dordrecht: Springer/Kluwer Academic Publishers.

Lukacs, J. R., and B. E. Hemphill. 1991. Dental Anthropology of Prehistoric Baluchistan: A Morphometric Approach to the Peopling of South Asia. In *Advances in Dental Anthropology,* ed. M. A. Kelley and C. S. Larsen, 77–119. New York: Wiley Liss.

Lukacs, J. R., and M. R. Joshi. 1992. Enamel Hypoplasias in Three Ethnic Groups of Northwest India. In *Recent Contributions to the Study of Enamel Developmental Defects,* ed. A. H. Goodman and L. Carpusso, 359–72. Chiete, Italy: *Paleopathology* Monographic Publication 2.

Lukacs, J. R., M. Joshi, and P. Makhija. 1983. Deciduous Tooth Crown Dimensions in Living and Prehistoric Populations of Western India. *American Journal of Physical Anthropology* 61 (3): 383–97.

Lukacs, J. R., and L. Largaespada. 2006. Explaining Sex Differences in Dental Caries Rates: Saliva, Hormones and "Life History" Etiologies. *American Journal of Human Biology* 18 (4): 540–55.

Lukacs, J. R., and L. L. Minderman. 1990. Agricultural Intensification and Dental Pathology at Mehrgahr, Pakistan. *American Journal of Physical Anthropology* 81 (2): 260.

Lukacs, J. R., and J. N. Pal. 1993. Mesolithic Subsistence in North India: Inferences from Dental Pathology and Odontometry. *Current Anthropology* 34 (5): 745–65.

———. 2003. Skeletal Variation among Mesolithic People of the Ganga Plain: New Evidence of Habitual Activity and Adaptation to Climate. *Asian Perspectives* 42 (2): 329–52.

———. 2004. Paleopathology and Subsistence Transition Theory: New Evidence from Mesolithic Skeletons from Damdama. In *Fifty Years of Indian Prehistory: Retrospect and Prospect*, ed. J. N. Pal. Prof. A. K. Varma Felicitation Volume. Allahabad: Swabha Prakashan.

Lukacs, J. R., and S. R. Walimbe. 1984. Deciduous Dental Morphology and the Biological Affinities of a Late Chalcolithic Skeletal Series from Western India. *American Journal of Physical Anthropology* 65 (1): 23–30.

———. 1986. *Excavations at Inamgaon,* vol. 2, *The Physical Anthropology of Human Skeletal Remains,* part 1: *An Osteobiographic Analysis.* Poona: Deccan College Post-Graduate and Research Institute.

———. 1998. Physiological Stress in Prehistoric India: New Data on Localized Hypoplasia of Primary Canines Linked to Climate and Subsistence Change. *Journal of Archaeogical Science* 25: 571–85.

———. 2000. Health, Climate and Culture in Prehistoric India: Conflicting Conclusions from Archaeology and Anthropology? In *South Asian Archaeology 1997,* vol. 1, ed. M. Taddei and G. DeMarco, 363–81. Rome: Instituto Italiano per L'Africa e L'Oriente.

———. 2005. Biological Responses to Subsistence Transitions in Prehistory: Diachronic Dental Changes at Chalcolithic Inamgaon. *Man and Environment* 30 (2): 24–43.

Lukacs, J. R., S. R. Walimbe, and G. C. Nelson. 2001. Enamel Hypoplasia and Childhood Stress in Prehistory: New Data from India and Southwest Asia. *Journal of Archaeological Science* 28: 1159–69.

Luoyang Museum. 1981. Excavation Summary Report of Luoyang Xigaoya Site. *Archaeological Journal* 7.

Ma, Xiaolin. 2003. Emergent Social Complexity in the Yangshao Culture: Analyses of Settlement Patterns and Faunal Remains from Lingbao, Western Henan, China. Ph.D. dissertation, La Trobe University, Australia.

———. 2005. *Emergent Social Complexity in the Yangshao Culture: Analyses of Settlement Patterns and Faunal Remains from Lingbao, Western Henan, China (c. 4900–3000 BC).* BAR International Series 1453. Oxford: British Archaeological Reports.

Ma, X., X. Li, and H. Yang. 2005. A Great Breakthrough in the Fifth Excavation at Xipo in Lingbao, Henan. *Zhongguo Wenwubao* 26: 1. Henan Provincial Institute of Cultural Relics and Archaeology.

———. 2006. A Study of Jade Articles from the Yangshao Cultural Cemetery at Xipo in Lingbao. *Zhongyuan Wenwu* 3: 72–76.

Maat, G. 2005. Two Millennia of Male Stature Development and Population Health in the Low Countries. *International Journal of Osteoarchaeology* 15 (4): 276–91.

Macchiarelli, R. 1989. Prehistoric Fish-eaters along the Eastern Arabian Coasts: Dental Variation, Morphology, and Oral Health in the Ra's al-Hamra Community, Qurum, Sultanate of Oman, 5th–4th Millennia BC. *American Journal of Physical Anthropology* 78: 575–94.

Madsen, T. 1991. The Social Structure of Early Neolithic Society in South Scandinavia. *Saarbrücker Beiträge zur Altertumskunde* 55: 489–96.

Magee, P. 1996a. The Chronology of the Southeast Arabian Iron Age. *Arabian Archaeology and Epigraphy* 7: 240–52.

———. 1996b. Excavations at Muweilah: Preliminary Report on the First Two Seasons. *Arabian Archaeology and Epigraphy* 7: 195–213.

Magoon, D., L. Norr, D. L. Hutchinson, and C. R. Ewen. 2001. An Analysis of Human

Skeletal Materials from the Snow Beach Site (8WA52). *Southeastern Archaeology* 20: 18–30.

Makowski, K. 1994. Proyecto Arqueológico Tablada de Lurín Pontifica Universidad Catolica del Peru: Reporte de las Temporadas 1991/1992 en Tablada de Lurín. Informe presentado al instituto nacional de cultura.

———. 2002. Power and Social Ranking at the End of the Formative Period: The Lower Lurin Valley Cemeteries. In *Andean Archaeology I: Variations in Sociopolitical Organization,* ed. W. H. Isbell and H. Silverman, 89–120. New York: Kluwer Academic/Plenum Publishers.

Maltby, M. 1996. The Exploitation of Animals in the Iron Age: The Archaeozoological Evidence. In *The Iron Age in Britain and Ireland: Recent Trends,* ed. T. C. Champion and J. R. Collis, 17–27. Sheffield, U.K.: J. R. Collis Publications.

Mamanova, M. M. 1978. *Demographiya UlaanGomskogo mogilnika Soyano-Tuvinskii kulitura V-III BC.* (The Demographical Investigation of UlaanGom Burial Cultures of Soyano-Tuva V–III BC.) Archaeology and Ethnography of Mongolia. Novosibirsk: Russian Academy of Sciences.

Manchester, K. 1991. Tuberculosis and Leprosy: Evidence for Interaction of Disease. In *Human Paleopathology,* ed. D. J. Ortner and A. C. Aufderheide, 23–35. Washington, D.C.: Smithsonian Institution Press.

Manzi, G., L. Salvadei, A. Vienna, and P. Passarello. 1999. Discontinuity of Life Conditions at the Transition from the Roman Imperial Age to the Early Middle Ages: Example from Central Italy Evaluated by Pathological Dental-Alveolar Lesions. *American Journal of Human Biology* 11 (3): 327–41.

Manzi, G., E. Sanandrea, and P. Passarello. 1997. Dental Size and Shape in the Roman Imperial Period: Two Examples from the Area of Rome. *American Journal of Physical Anthropology* 102 (4): 469–79.

Marcsik, A., E. Fóthi, and A. Hegyi. 2002. Paleopathological Changes in the Carpathian Basin in the 10th and 11th Centuries. *Acta Biologica Szegediensis* 46: 95–99.

Márquez Morfín, R. L., and A. del Angel. 1997. Height among the Prehistoric Maya of the Yucatan Peninsula: A Reconsideration. In *Bones of the Maya,* ed. S. L. Whittington and D. M. Reed, 51–61. Washington, D.C.: Smithsonian Institution Press.

Márquez Morfín, R. L., R. Mcaa, R. Storey, and A. Del Angel. 2002. Health and Nutrition in Prehispanic Mesoamerica. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 307–38. Cambridge, U.K.: Cambridge University Press.

Martin, D. 1994. Patterns of Diet and Disease Profiles for the Prehistoric Southwest. In *Themes in Southwest Prehistory*, ed. G. J. Gumerman, 87–108. Santa Fe, N.Mex.: School of American Research.

Massler, M., I. Schour, and H. G. Pancher. 1941. Developmental Patterns of the Child as Reflected in the Calcification Pattern of the Teeth. *American Journal of the Diseases of Children* 62: 33–67.

Mayes, A. T. 2001. Patterns through Time: Interactions between Changes in Subsistence and Human Dentition at Illinois Bluff, Jersey County, Illinois, and Spiro Mounds, Oklahoma. Ph.D. dissertation, University of Colorado, Boulder.

Mays, S., G. Crane-Kramer, and A. Bayliss. 2003. Two Probable Cases of Treponemal Disease of Medieval Date from England. *American Journal of Physical Anthropology* 120: 133–43.

McAnany, P. A., ed. 2004. *K'axob: Ritual, Work, and Family in an Ancient Maya Village.* Los Angeles: Cotsen Institute of Archaeology, University of Californa.

McCaw, M. forthcoming. The Faunal Remains: Major Variables. In *The Origins of Angkor Volume II: The Excavations at Noen U-Loke*, ed. C. F. W. Higham, A. Kijingam, and S. Talbot. Bangkok: Fine Arts Department of Thailand.

McGrath, W. 1988. Social Networks of Disease Spread in the Lower Illinois Valley: A Simulation Approach. *American Journal of Physical Anthropology* 77 (4): 483–96.

McNeill, W. H. 1976. *Plagues and Peoples.* New York: Anchor Press.

Meiklejohn, C. 1993. You Can't Live Without It, but You Can't Always Live With It. In *Culture and Environment: A Fragile Coexistence,* ed. R. Jamison, S. Abonyi, and N. Mirau, 11–16. Calgary: University of Calgary Press.

Meiklejohn, C. A., A. Agelarakis, P. A. Akkerma, P. E. L. Smith, and R. Solecki. 1992. Artificial Cranial Deformation in the Proto-Neolithic and Neolithic Near East and Its Possible Origin: Evidence from Four Sites. *Paléorient* 18 (2): 83–97.

Meiklejohn, C., E. B. Petersen, and V. Alexandersen. 1998. The Later Mesolithic Population of Sjælland, Denmark, and the Neolithic Transition. In *Harvesting the Sea, Farming the Forest,* ed. M. Zvelebil, L. Domanska, and R. Dennell, 203–12. Sheffield, U.K.: JR Collins.

Meiklejohn, C., C. Schentag, A. Venema, and P. Key. 1984. Socioeconomic Change and Patterns of Pathology and Variation in the Mesolithic and Neolithic of Western Europe: Some Suggestions. In *Paleopathology at the Origins of Agriculture of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 75–100. Orlando, Fla.: Academic Press.

Meiklejohn, C., and M. Zvelebil. 1991. Health Status of European Populations at the Agricultural Transition and the Implications for the Adoption of Farming. In *Health in Past Societies,* ed. H. Bush and M. Zvelebil, 129–45. BAR International Series 567. Oxford: British Archaeological Reports.

Mercador, J. ed. 2003. *Under the Canopy.* New Brunswick, N.J.: Rutgers University Press.

Milanich, J. T. 1994. *Archaeology of Pre-Columbian Florida.* Gainesville: University Press of Florida.

Miller-Shaivitz, P., and M. Y. Iscan. 1991. The Prehistoric People of Fort Center: Physical and Health Characteristics. In *What Mean These Bones? Studies in Southeastern Bioarchaeology,* ed. M. L. Powell, P. S. Bridges, and A. M. W. Mires, 131–47. Tuscaloosa: University of Alabama Press.

Milner, G. R. 1991. Health and Cultural Change in the Late Prehistoric American Bottom, Illinois. In *What Mean These Bones? Studies of Southeastern Bioarchaeology,* ed. M. L. Powell, P. Bridges, and A. M. W. Mires, 52–69. Tuscaloosa: University of Alabama Press.

———. 1992. Disease and Sociopolitical Systems in Late Prehistoric Illinois. In *Disease and Demography in the Americas,* ed. J. W. Verano and D. H. Ubelaker, 103–16. Washington, D.C.: Smithsonian Institution Press.

———. 1995. An Osteological Perspective on Prehistoric Warfare. In *Regional Approaches to Mortuary Analysis,* ed. L. A. Beck, 221–24. New York: Plenum Press.

———. 1998. *The Cahokia Chiefdom.* Washington, D.C.: Smithsonian Institution Press.

Milner, G. R., and V. G. Smith. 1989. Carnivore Alteration of Human Bone from a Late Prehistoric Site in Illinois. *American Journal of Physical Anthropology* 79 (1): 43–49.

Milner, G. R., J. W. Wood, and J. L. Boldsen. 2000. Paleodemography. In *Biological An-*

thropology of the Human Skeleton, ed. A. K. Katzenberg and S. R. Saunders, 467–97. New York: Wiley Liss.

Milton, J. S. 1994. *Estadística para Biología y ciencias de la salud.* Madrid: McGraw and Hill.

Mitchell, N. 1975. Paleopathology as Archaeology: The Humber Site (22Co601), Coahoma Co, Mississippi. M.A. thesis, Department of Sociology and Anthropology, University of Mississippi, Oxford.

Mitchell, P. 2002. *The Archaeology of Southern Africa.* Cambridge, U.K.: Cambridge University Press.

Molleson, T. 1994. The Eloquent Bones of Abu Hureyra. *Scientific American* (August): 70–75.

Molnar, S. 1971. Human Tooth Wear, Tooth Function and Cultural Variability. *American Journal of Physical Anthropology* 34: 175–90.

———. 1992. *Human Variation: Races, Types, and Ethnic Groups.* Englewood Cliffs, N.J.: Prentice Hall.

Monahan, E. I., and D. S. Weaver. 1996. Dental Health in Late Woodland Subsistence in Coastal North Carolina. *American Journal of Physical Anthropology* supplement 22: 171–72.

Moorrees, C. F. A., E. A. Fanning, and E. E. J. Hunt. 1963a. Age Formation by Stages for Ten Permanent Teeth. *Journal of Dental Research* 42: 1490–1592.

———. 1963b. Formation and Resorption of Three Deciduous Teeth in Children. *American Journal of Physical Anthropology* 21: 205–13.

Morris, A. G. 1922a. *A Master Catalogue: Holocene Human Skeletons from South Africa.* Johannesburg, South Africa: Witwatersrand University Press.

———. 1992b. *The Skeletons of Contact.* Johannesburg, South Africa: Witwatersrand University Press.

Morris, A. G., and J. Parkinton. 1982. Prehistoric Homicide: A Case of Violent Death on the Cape South Coast, South Africa. *South Africa Journal of Science* 78: 167–69.

Morris, A. G., A. I. Thackeray, and J. F. Thackeray. 1987. Late Holocene Human Skeletal Materials from Snuifklip, near Vleesbaai, Southern Cape. *South African Archaeological Bulletin* 42: 153–60.

Morse, D. 1969. *Ancient Disease in the Midwest.* Reports of Investigations 15. Springfield: Illinois State Museum.

Moseley, M. E. 1975. *The Maritime Foundations of Andean Civilization.* Menlo Park, Calif.: Cummings Publishing.

———. 1992a. Maritime Foundations and Multilinear Evolution. *Andean Past* 3: 5–42.

———. 1992b. *The Incas and Their Ancestors.* London: Thames and Hudson.

Moss, M., and R. W. Young. 1960. A Functional Approach to Craniology. *American Journal of Physical Anthropology* 18: 281–92.

Muñoz, I. 1982. Las sociedades costeras de Arica durante el periodo arcaico y sus vinculaciones con la costa Peruana. *Chungara* 9: 124–51.

———. 1983. La fase Alto Ramírez del extremo norte de Chile: Asentamientos aldeanos en los valles costeros de Arica. *Documentos de Trabajo* 3: 3–42.

———. 1987. Enterramientos en túmulos en el valle de Azapa: Nuevas evidencias para definir la fase Alto Ramírez en el extremo norte de Chile. *Chungara* 19: 93–127.

———. 1989. El Periódo Formativo en el Norte Grande 100 A.C. a 500 D.C. In *Culturas de Chile: Prehistoria, desde sus orígenes hasta la civilización,* ed. J. Hidalgo, V. Schiappacasse, H. Niemeyer, C. Aldunate, and S. Iván, 107–28. Santiago, Chile: Editorial Andrés Bello.

Muñoz, I., B. T. Arriaza, and A. C. Aufderheide. 1993. *Acha-2 y el orígen del poblamiento humano de Arica.* Arica, Chile: Ediciones Universidad de Tarapacá.

Muñoz, I., and J. Chacama. 1993. Arqueología: Patrón de asentamiento y cronología de Acha-2. In *Acha-2 y el orígen del poblamiento humano de Arica,* ed. I. Muñoz, B. T. Arriaza, and A. C. Aufderheide, 21–46. Arica, Chile: Ediciones Universidad de Tarapacá.

Munson, P. J. 1984. Experiments and Observations on Aboriginal Wild Plant Utilization in Eastern North America. *Prehistory Research Series* 4 (2). Indianapolis: Indiana Historical Society.

———. 1988. Late Woodland Settlement and Subsistence in Temporal Perspective. In *Culture Change in the Eastern Woodlands during the Late Woodland Period,* ed. R. W. Yerkes, 7–16. Ohio State University Department of Anthropology Occasional Papers in Anthropology 3, Columbus.

———. 1989. Still More on the Antiquity of Maple Sugar and Syrup in Aboriginal Eastern North America. *Journal of Ethnobiology* 9 (2): 159–70.

Murphy, K. A. 1998. Human Bones Tell Tales: The Role of Herding and Farming in the Diet of Prehistoric Inhabitants from Kgaswe, Botswana. *Nyame Akuma* 50: 55.

Murra, J. 1985. The Limits and Limitations to the "Vertical Archipelago" in the Andes. In *Andean Ecology and Civilization: An Interdisciplinary Perspective on Andean Ecological Complementarity,* ed. S. Madusa, I. Shimadam, and C. Morris, 3–15. Tokyo: University of Tokyo Press.

Murray, K. A., and J. C. Rose. 1995. Bioarcheology of Missouri. In *Holocene Human Adaptations in the Missouri Prairie-Timberlands,* ed. W. R. Wood, M. J. O'Brien, K. A. Murray, and J. C. Rose, 112–47. Arkansas Archeological Survey Research Series 45, Fayetteville.

Murray, M. L., and M. J. Schoeninger. 1988. Diet, Status, and Complex Social Structure in Iron Age Central Europe: Some Contributions of Bone Chemistry. In *Tribe and Polity in Late Prehistoric Europe,* ed. D. B. Gibson and M. N. Geselowitz, 155–76. New York: Plenum Press.

Naran, B. 2003. Paleopathological Cases from the Xiongnu Period in Mongolia. Paper presented at 30th Annual Meeting of the Paleopathology Association, Tempe, Arizona.

———. 2004. Traumatic Lesions in Ancient Nomads from Western Mongolia. Paper presented at 31st Annual Meeting of the Paleopathology Association, Tampa, Florida.

Nash, C. H., and R. Gates. 1962. Chucalissa Indian Town. *Tennessee Historical Quarterly* 21: 103–21.

Nathan, H., and N. Haas. 1966. Cribra Orbitalia: A Bone Condition of the Orbit of Unknown Nature. *Israel Journal of Medical Science* 2: 171–91.

Nelson, B. A., D. L. Martin, A. C. Swedlund, P. R. Fish, and G. J. Armelagos. 1994. Studies in Disruption: Demography and Health in the Prehistoric American Southwest. In *Understanding Complexity in the Prehistoric Southwest,* ed. G. J. Gumermann and M. Gell-Mann, 59–112. Reading, Mass.: Addison-Wesley.

Nelson, K. M. 1999. The Dental Health of the People of Noen U-Loke: A Prehistoric Iron Age Site in Northeast Thailand. M.S. thesis, University of Otago, Dunedin, New Zealand.

Neves, W. A., A. M. Barros, and M. A. Costa. 1999. Incidence and Distribution of Postcranial Fractures in the Prehistoric Population of San Pedro De Atacama, Northern Chile. *American Journal of Physical Anthropology* 109 (2): 253–58.

Neves, W. A., and V. Wesolowski. 2002. Economy and Nutrition in Coastal Brazil. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 376–400. Cambridge, U.K.: Cambridge University Press.

Newman, M. T. 1951. Skeletal Material. In *The Archaeology of the Bynum Mounds, Mississippi,* ed. J. L. Cotter and J. M. Corbett. Archaeological Research Series 1. Washington, D.C.: National Park Service, U.S. Dept. of the Interior.

———. 1960 Adaptations in the Physique of American Aboriginals to Nutritional Factors. *Human Biology* 32: 288–313.

———. 1962. Evolutionary Changes in Body Size and Head Form in American Indians. *American Anthropologist* 64(2): 1237–57.

Nielsen, H. A. 1906. Bidrag til Danmarks Forhistoriske Befolknings (Særlig Stenalderfolkets). *Anthropologi. Aarbøger for Nordisk Oldkyndighed og Historie* 1906: 237–318.

Nørby, S., and J. Saillard. 1998. På Sporet af Danskernes Oprindelse: Palæolitisk og Neolitisk Mitochondrie-DNA i den Nutidige Danske Befolkning. 3. Nordiske seminar om Biologisk antropologi. Clara Lachmann Symposium, 40–42. Copenhagen: Københavns Universitet, Antropologisk Laboratorium.

Norr, L. 2002. Stable Isotope Analysis and Dietary Inference. In *Foraging, Farming, and Coastal Biocultural Adaptation in Late Prehistoric North Carolina,* ed. D. L. Hutchinson, 178–205. Gainesville: University Press of Florida.

Norton, D. C. 2004. Intersite Relationship Analysis: Comparative Study between Two Prehistoric Cemeteries in Northeastern Alabama Using Discrete Genetic Traits and Mortuary Material Remains. M.A. thesis, Department of Anthropology and Sociology, University of Southern Mississippi, Hattiesburg.

Nuñez, L. A. 1967. Sobre los complejos culturales Chinchorro y faldas del Morro del norte de Chile. *Rehue* 2: 111–42.

———. 1989. Hacia la producción de alimentos y la vida sedentaria. In *Culturas de Chile: Prehistoria, desde sus orígenes hasta la civilización,* ed. J. Hidalgo, V. Schiappacasse, H. Niemeyer, C. Aldunate, and S. Iván, 81–105. Santiago, Chile: Editorial Andrés Bello.

Nuñez, L. A., and T. Dillehay. 1995. *Movilidad giratoria, armonía social y desarrollo en los Andes meridionales: Patrones de tráfico e interacción económica.* Antofagasta, Chile: Universidad del Norte.

Nuño, S., and A. Barros. 1984. *La tierra en que vivimos: Una historia natural.* Santiago, Chile: Editorial Antártica.

O'Gorman, J. A., and H. Hassen. 2000. Late Woodland in the Mississippi Valley of West-Central Illinois. In *Late Woodland Societies: Tradition and Transformation across the Midcontinent,* ed. T. E. Emerson, D. L. McElrath, and A. C. Fortier, 277–300. Lincoln: University of Nebraska Press.

O'Reilly, D. J. W. 2000. From the Bronze Age to the Iron Age in Thailand: Applying the Heterarchical Approach. *Asian Perspectives* 39: 1–19.

Ortner, D. J. 1992. Skeletal Pathology: Probabilities, Possibilities and Impossibilities. In *Disease and Demography in the Americas,* ed. J. W. Verano and D. H. Ubelaker, 5–14. Washington, D.C.: Smithsonian Institution Press.

———. 1998. Male-Female Immune Reactivity and Its Implications for Interpreting Evidence in Human Skeletal Pathology. In *Sex and Gender in Paleopathological Perspective,* ed. A. Grauer and P. Stuart Macadam, 79–92. Cambridge, U.K.: Cambridge University Press.

Ortner, D. J., and A. C. Aufderheide, eds. 1991. *Human Paleopathology.* Washington, D.C.: Smithsonian Institution Press.

Ortner, D. J., W. Butler, J. Cafarella, and L. Milligan. 2001. Evidence of Probable Scurvy in Subadults from Archaeological Sites in North America. *American Journal of Physical Anthropology* 114: 343–51.

Ortner, D. J., and M. F. Ericksen. 1997. Bone Changes in Human Skull Probably Resulting from Scurvy in Infancy and Childhood. *International Journal of Osteoarchaeology* 7: 212–20.

Ortner, D. J., E. Kimmerle, and M. Diez. 1999. Skeletal Evidence of Scurvy in Archeological Skeletal Samples from Peru. *American Journal of Physical Anthropology* 108: 321–31.

Ortner, D. J., and W. G. Putschar. 1985. *Identification of Pathological Conditions in Human Skeletal Remains.* Washington, D.C.: Smithsonian Institution Press.

Owsley, D. W. 1991. Temporal Variation in Femoral Cortical Thickness of North American Plains Indians. In *Human Paleopathology,* ed. D. J. Ortner and A. C. Aufderheide, 105–10. Washington, D.C.: Smithsonian Institution Press.

———. 1992. Demography of Prehistoric and Early Historic Northern Plains Populations. In *Disease and Demography in the Americas,* ed. J. W. Verano and D. H. Ubelaker, 75–86. Washington, D.C.: Smithsonian Institution Press.

Owsley, D. W., and R. L. Jantz. 1999. Databases for Paleo-American Skeletal Biology Research. In *Who Were the First Americans?* ed. R. Bonnichsens, 79–96. Proceedings of the 58th Annual Biology Colloquium, Oregon State University. A Peopling of the Americas Publication, Center for the Study of the First Americans. Corvallis: Oregon State University.

Oxenham, M. F. 2000. Health and Behavior during the Mid-Holocene and Metal Period of Northern Viet Nam. Ph.D. dissertation, Northern Territory University, Australia.

———. 2002. Human Skeletal Indications of the Emergence of Chronic Infectious Disease in Northern Viet Nam. *American Journal of Physical Anthropology* supplement 34: 121.

———. 2004. Biological Responses to Change in Prehistoric Sub-tropical Viet Nam. Paper Presented to the Conference on Ancient Health, Clearwater Beach, Florida, April 2004.

Paine, R. R., ed. 1997. *Integrating Archaeological Demography: Multidisciplinary Approaches to Prehistoric Population.* Carbondale, Ill.: Center for Archaeological Investigations.

Palfi, G. 2002. Paleoepidemiological Investigations of Neolithic Skeletal Material in the Area of the Middle Elbe and Saale River, Germany. In *Ecological Aspects of Past Human Settlements in Europe,* ed. P. Bennike, E. B. Bodzsar, and C. Susanne, 193–210. Budapest: Eotvos University Press.

Palfi, G., O. Dutour, J. Deak, and I. Hutas. 1999. *Tuberculosis Past and Present.* Szeged, Hungary: Golden Book Publishers.

Palmer, A. R. 1994. Fluctuating Symmetry Analysis: A Primer. In *Developmental Instability: Its Origins and Evolutionary Implications,* ed. T. Markow, 355–63. Dordrecht: Kluwer Academic Publishers.

Palmer, A. R., and C. Strobeck. 1997. Fluctuating Asymmetry and Developmental Stability: Heritability of Observed Variation vs. Heritability of Inferred Cause. Commentary. *Journal of Evolutionary Biology* 10: 39–49.

Panja, S. 1996. Mobility Strategies, Site Structure, and Settlement Organization: An Actualistic Perspective. *Man and Environment* 19: 58–73.

———. 1999. Mobility and Subsistence Strategies: A Case Study of Inamgaon, a Chalcolithic Site in Western India. *Asian Perspectives* 38: 154–85.

Panter-Brick, C., R. H. Layton, and P. Rowley-Conway, eds. 2001. *Hunter-Gatherers: An Interdisciplinary Perspective.* Cambridge, U.K.: Cambridge University Press.

Papathanasiou, A. 2005. Health Status of the Neolithic Population of Alepotrypa Cave, Greece. *American Journal of Physical Anthropology* 126: 377–90.

Parham, K. R. 1982. A Biocultural Approach to the Skeletal Biology of the Dallas People from Toqua. M.A. thesis, Department of Anthropology, University of Tennessee, Knoxville.

Parham, K. R., and G. T. Scott. 1980. Porotic Hyperostosis: A Study of Disease and Culture at Toqua (40MR6), a Late Mississippian Site in Eastern Tennessee. In *Skeletal Biology of Aboriginal Populations in the Southeastern United States,* ed. P. Willey and F. H. Smith, 39–51. Miscellaneous Paper 5. Knoxville: Tennessee Anthropological Association.

Parker Pearson, M. 1993. *Bronze Age Britain.* London: English Heritage.

———. 1999. The Earlier Bronze Age. In *The Archaeology of Britain: An Introduction from the Upper Palaeolithic to the Industrial Revolution,* ed. J. R. Hunter and I. Ralston, 77–94. London: Routledge.

Parkington, J. 1998. Resolving the Past: Gender in the Archaeological Record of the Western Cape. In *Gender in African Prehistory,* ed. S. Kent, 25–38. Walnut Creek, Calif.: Altamira Press.

Patrick, M. K. 1989. An Archaeological, Anthropological Study of the Human Skeletal Remains from the Oakhurst Rockshelter, George, Cape Province, Southern Africa. M.S. dissertation, University of Cape Town.

Patrucco, R., R. Tello, and D. Bonavia. 1983. Parasitological Studies of Coprolites of Pre-Hispanic Peruvian Populations. *Current Anthropology* 24: 393–94.

Patterson, D. K. 1986. Changes in Oral Health. *Canadian Journal of Anthropology* 5 (2): 3–13.

Patterson, T. C. 1966. *Pattern and Process in Early Intermediate Period Pottery of the Central Coast of Peru.* Berkeley: University of California Press.

Pearsall, D. M. 1992. The Origins of Plant Cultivation in South America. In *Origins of Agriculture: An International Perspective,* ed. C. W. Cowan and P. J. Watson, 173–205. Washington, D.C.: Smithsonian Institution Press.

———. 2003. Plant Food Resources of the Ecuadorian Formative: An Overview and Comparison to the Central Andes. In *Archaeology of Formative Ecuador,* ed. J. S. Raymond and R. L. Burger, 213–57. Washington, D.C.: Dumbarton Oaks.

Pechenkina, E. A. 2002. Diet and Health Changes among the Millet Growing Farmers of Northern China in Prehistory. Ph.D. thesis, University of Missouri–Columbia.

Pechenkina, E. A., S. H. Ambrose, X. Ma, and R. A. Benfer Jr. 2005. Reconstructing Northern Chinese Neolithic Subsistence Practices by Isotopic Analysis. *Journal of Archaeological Science* 32: 1176–1189.

Pechenkina, E. A., R. A. Benfer Jr., and W. Zhijun. 2002. Diet and Health Changes with the Intensification of Millet Agriculture at the End of the Chinese Neolithic. *American Journal of Physical Anthropology* 117: 15–36.

Penton, M. 1995. Bioarchaeology and Subsistence in the Lower Mississippi Valley: Mangum Site, Mississippi. M.A. thesis, Department of Anthropology, University of Oregon, Eugene.

Perzigian, A. J., P. A. Tench, and D. J. Braun. 1984. Prehistoric Health in the Ohio River Valley. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 347–66. Orlando, Fla.: Academic Press.

Peters, J., D. Helmer, A. von den Driesch, and M. Saña Segui. 1999. Early Animal Husbandry in the Northern Levant. *Paléorient* 25: 27–47.

Petersen, H. C. 1988. Studier over Dansk Stenalders Biologiske Antropologi. Master's thesis, Institute of Genetics and Ecology, University of Aarhus.

———. 1992. Multivariate Studies of Prehistoric Human Skeletal Remains. Ph.D. thesis, Institute of Genetics and Ecology, University of Aarhus.

Peterson, J. 1997. Tracking Activity Patterns through Skeletal Remains: A Case Study from Jordan and Palestine. In *The Prehistory of Jordan II: Perspectives from 1997,* ed. H. G. Gebel, Z. Kafafi, and G. O. Rollefson, 475–492. Berlin: Ex Oriente.

———. 1998. The Natufian Hunting Conundrum: Spears, Atlatls, or Bows? Musculoskeletal and Armature Evidence. *International Journal of Osteoarchaeology* 8: 378–89.

Pfeiffer, S., and C. Crowder. 2004. An Ill Child among Mid-Holocene Foragers of Southern Africa. *American Journal of Physical Anthropology* 123: 23–29.

Pfeiffer, S., and J. Sealy. 1998. Reconstructing Diet and Behavior of Later Stone Age People of the Southern Cape, South Africa. *Nyame Akuma* 50: 56–57.

———. 2006. Body Size among Holocene Foragers of the Cape Ecozone, Southern Africa. *American Journal of Physical Anthropology* 129: 1–11.

Pfeiffer, S., and J. Stock. 2002. Upper Limb Morphology and the Division of Labor among Southern African Holocene Foragers. *American Journal of Physical Anthropology* supplement 34: 124.

Pfeiffer, S., and N. J. van der Merwe. 2004. Cranial Injuries to Later Stone Age Children from the Modder River Mouth, Southwestern Cape, South Africa. *South Africa Archaeological Bulletin* 59: 59–65.

Pfeiffer, S., N. J. van der Merwe, J. E. Parkington, and R. Yates. 1999. Violent Human Death in the Past: A Case from the Western Cape. *South Africa Journal of Science* 95: 137–40.

Phillips, C. S. 1997. The Pattern of Settlement in the Wadi al-Qawr. *Proceedings of the Seminar for Arabian Studies* 27: 205–18.

Pietrusewsky, M. 1974. *Non Nok Tha: The Human Skeletal Remains from the 1966 Excavations at Non Nok Tha, Northeast Thailand.* University of Otago Studies in Prehistoric Anthropology 6. Dunedin, New Zealand: University of Otago.

Pietrusewsky, M., and M. T. Douglas. 2002a. *Ban Chiang, a Prehistoric Village Site in Northeast Thailand I: The Human Skeletal Remains.* University Museum Memoir Series. Philadelphia: University Museum, University of Pennsylvania.

———. 2002b. Intensification of Agriculture at Ban Chiang: Is There Evidence from the Skeletons? *Asian Perspectives* 40: 157–78.

Pietrusewsky, M., M. T. Douglas, and R. M. Ikehara-quebral. 1997. An Assessment of Health and Disease in the Prehistoric Inhabitants of the Mariana Islands. *American Journal of Physical Anthropology* 104: 315–42.

Piontek, J., and V. Vancata. 2002. Genetic Transition to Agriculture in Europe. In *Ecological Aspects of Past Human Settlements in Europe,* ed. P. Bennike, E. B. Bodzsar, and C. Susanne, 61–92. Budapest: Eotvos University Press.

Potts, D. T. 1990a. *The Arabian Gulf in Antiquity,* vol. 1, *From Prehistory to the Fall of the Archaemenid Empire.* Oxford, U.K.: Clarendon Press.

———. 1990b. *The Arabian Gulf in Antiquity,* vol. 2, *From Alexander the Great to the Coming of Islam.* Oxford, U.K.: Clarendon Press.
———. 1993a. Four Seasons of Excavation at Tell Abraq. *Proceedings of the Seminar for Arabian Studies* 23: 117–26.
———. 1993b. The Late Prehistoric, Protohistoric, and Early Historic Periods in Eastern Arabia, ca. 5000–1200 BC. *Journal of World Prehistory* 7 (2): 163–212.
———. 1993c. A New Bactrian Find from Southeastern Arabia. *Antiquity* 67: 591–96.
———. 1997. Before the Emirates: An Archaeological and Historical Account of Developments in the Region c. 5000 BC to 676 AD. In *Perspectives on the United Arab Emirates,* ed. E. Ghareeb and I. al Abed, 36–73. London: Trident Press.
———. 1998a. Maritime Beginnings. In *Waves of Time: The Maritime History of the United Arab Emirates,* ed. P. Hellyer, 8–43. London: Trident Press.
———. 1998b. Seas of Change. In *Waves of Time: The Maritime History of the United Arab Emirates,* ed. P. Hellyer, 44–67. London: Trident Press.
Potts, D. T., D. Barker, S. Blau, M. Riley, L. Weeks, and M. Ziolkowski. Forthcoming. Sharm Excavations. *Arabian Archaeological Epigraphs* 10 (1).
Powell, M. L. 1983. Biocultural Analyses of Human Skeletal Remains from the Lubbub Creek Archaeological Locality. In *Prehistoric Agricultural Communities in West Central Alabama,* vol. 2, ed. C. S. Peebles, 430–466. Report to the U.S. Army Corps of Engineers, Mobile District, Mobile.
———. 1985. The Analysis of Dental Wear and Caries for Dietary Reconstruction. In *The Analysis of Prehistoric Diets,* ed. R. I. Gilbert and J. H. Mielke, 307–38. London: Academic Press.
———. 1988. *Health and Status in Prehistory: The Case of Moundville.* Washington, D.C.: Smithsonian Institution Press.
———. 1991. Ranked Status and Health in the Mississippian Chiefdom at Moundville. In *What Mean These Bones? Studies of Southeastern Bioarchaeology,* ed. M. L. Powell, P. S. Bridges, and A. M. W. Mires, 22–51. Tuscaloosa: University of Alabama Press.
———. 1998. Of Time and the River: Perspectives on Health during the Moundville Chiefdom. In *Archaeology of the Moundville Chiefdom,* ed. V. J. Knight and V. P. Steponaitis, 102–19. Washington, D.C.: Smithsonian Institution Press.
Powell, M. L., P. S. Bridges, and A. M. W. Mires, eds. 1991. *What Mean These Bones? Studies of Southeastern Bioarchaeology.* Tuscaloosa: University of Alabama Press.
Powell, M. L., and D. C. Cook. 2005. *The Natural History of Syphilis.* Gainesville: University Press of Florida.
Power, C. 1993. Reconstructing Patterns of Health and Dietary Change in Irish Prehistoric Populations. *Ulster Journal of Archaeology* 56: 9–17.
Puwastien, P., M. Raroengwichit, P. Sungpuag, and K. Judprasong. 1999. *Thai Food Composition Tables.* Bangkok: Institute of Nutrition, Mahidol University.
Quilter, J. 1989. *Life and Death at Paloma: Society and Mortuary Practices in a Preceramic Peruvian Village.* Iowa City: University of Iowa Press.
Quintanilla, V. 1983. *Biogeografía.* Colección geográfica de Chile. Santiago, Chile: Instituto Geográfico Militar.
Raczek, T. P. 2003. Subsistence Strategies and Social Practice: Change and Continuity in the Late Deccan Chalcolithic. *Asian Perspectives* 42 (2): 247–66.
Raff, J., D. C. Cook, and F. Kaestle. 2006 Tuberculosis in the New World: A Study of Ribs from the Schild Mississippian Population, West-Central Illinois. *Memórias do Instituto Oswaldo Cruz*. 101 (Suppl 2): 25–27.

Rafferty, J. 1994. Gradual or Stepwise Change: The Development of Sedentary Settlement Patterns in Northeast Mississippi. *American Antiquity* 59: 405–25.

Raposo, L. 1994. Concheiros de Muge: Os "Bons selvagens" Afinal Eram Maus? In *A linguagem das coisas,* ed. L. Raposo and A. C. Silva, 311–18. Lisbon: Europa-América.

Rathbun, T. A., and J. P. Scurry. 1991. Status and Health in Colonial South Carolina: Belleview Plantation, 1738–1756. in *What Mean These Bones? Studies of Southeastern Bioarchaeology,* ed. M. L. Powell, P. S. Bridges, and A. M. W. Mires, 148–64. Tuscaloosa: University of Alabama Press.

Ravines, R. 1985. *Inventario de monumentos arqueológicos del Perú.* Lima: Municipalidad de Lima Metropolitana—Instituto Nacional de Cultura.

Reinhard, K. J., and A. C. Aufderheide. 1990. Diphyllobothriasis in Prehistoric Chile and Peru: Adaptive Radiation of a Helminth Species to Native American Populations. *Paleopathology Newsletter* 72: 18–19.

Reinhard, K. J., and O. Urban. 2003. Diagnosing Ancient Diphyllobothriasis from Chinchorro Mummies. *Memorias do Instituto Oswaldo Cruz* 98 supplement, no. 1: 191–93.

Reitz, E. J. 1986. Faunal Remains from Paloma, an Archaic Site in Perú. *American Anthropology* 90: 310–22.

———. 1993. Evidence for Animal Use at the Missions of Spanish Florida. In *The Spanish Missions of La Florida,* ed. B. G. McEwan, 376–98. Gainesville: University Press of Florida.

———. 1988. Preceramic Animal Use on the Central Coast. In *Economic Prehistory of the Central Andes*, ed. E. S. Wing and J. C. Wheeler, 31–55. London: British Archaeological Reports, International Series 427.

———. 2001. Fishing in Peru between 10000 and 3750 BC. *International Journal of Osteoarchaeology* 11: 163–71.

Ren Shinan. 1996. Several Major Achievements in Early Neolithic China, ca. 5000 BC. *Kaogu* 1: 37–49.

Ren Shinan and Yaoli Wu. 1999. Fifty Years of Neolithic Archaeology in China. *Kaogu* 9: 11–22.

Rheinholdt, J. G., H. Hedayati, A. Lahimgarzaden, and K. Nasr. 1973. Zinc, Calcium, Phosphorus and Nitrogen Balances of Iranian Villagers Following Change from Phytate-Rich to Phytate-Poor Diets. *Ecology of Food and Nutrition* 2: 137–67.

Richards, M., H. Corte-Real, P. Forster, V. Macaulay, H. Wilkinson-Herbots, A. Demaine, S. Papiha, R. Hedges, H. J. Bandelt, and B. Sykes. 1996. Paleolithic and Neolithic Lineages in the European Mitochondrial Gene Pool. *American Journal of Genetics* 59: 185–203.

Richards, M., and E. Koch. 2001. Neolitisk Kost. (Neolithic Diet.) *Aarbøger for Nordisk Oldkyndighed og Historie* 1999: 7–17.

Riley, T. J., G. R. Walz, C. J. Bareis, A. C. Fortier, and K. E. Parker. 1994. Accelerator Mass Spectrometry (AMS) Dates Confirm Early *Zea mays* in the Mississippi River Valley. *American Antiquity* 59: 490–98.

Rivera, M. 1985. Alto Ramírez y Tiwanaku: Un caso de interpretación simbólica a través de datos arqueológicos en el área de Los Valles Occidentales S. del Perú y N. de Chile. *Diálogo Andino* 4: 39–58.

———. 1994. Hacia la complejidad social y política: El desarrollo Alto Ramírez del norte de Chile. *Diálogo Andino* 13: 9–37.

Roberts, C. 2000. Trauma in Biocultural Perspective: Past, Present and Future Work in Britain. In *Human Osteology in Archaeology and Forensic Science,* ed. M. Cox and S. Mays, 337–56. London: Greenwich Medical Media.

———. 2002. The Antiquity of Leprosy in Britain: The Skeletal Evidence. In *The Past and Present of Leprosy: Proceedings of the 3rd International Congress on the Evolution and Palaeoepidemiology of the Infectious Diseases,* ed. C. Roberts, M. E. Lewis, and K. Manchester, 213–22. Oxford, U.K.: Archaeopress.

Roberts, C., and J. E. Buikstra. 2003. *The Bioarchaeology of Tuberculosis: A Global View on a Reemerging Disease.* Gainesville: University Press of Florida.

Roberts, C., and M. Cox. 2003. *Health and Disease in Britain: From Prehistory to the Present Day.* Stroud, U.K.: Sutton Publishing.

Roberts, C., and M. E. Lewis. 2002. Ecology and Infectious Disease in Britain from Prehistory to the Present: The Case of Respiratory Infections. In *Ecological Aspects of Past Human Settlements in Europe,* ed. P. Bennike, E. B. Bodzsar, and C. Susanne, 179–92. Budapest: Eotvos University.

Roberts, C., M. E. Lewis, and K. Manchester, eds. 2002. *The Past and Present of Leprosy: Proceedings of the 3rd International Congress on the Evolution and Palaeoepidemiology of the Infectious Diseases.* Oxford, U.K.: Archaeopress.

Roberts, C. M., and K. Manchester. 2005. *The Archaeology of Disease.* 3rd edition. Ithaca, N.Y.: Cornell University Press.

Rollefson, G. O. 1996. The Neolithic Devolution: Ecological Impact and Cultural Compensation at ʿAin Ghazal, Jordan. In *Retrieving the Past,* ed. J. D. Seger, 219–29. Winona Lake, Ind.: Eisenbrauns.

Rollefson, G. O., and I. Köhler-Rollefson. 1989. The Collapse of Early Neolithic Settlements in the Southern Levant. In *People and Culture in Change,* ed. I. Hershkovitz, 73–89. BAR International Series 508. Oxford: British Archaeological Reports.

Rollefson, G. O., A. H. Simmons, M. L. Donaldson, W. Gillespie, Z. Kafafi, I. Köhler-Rollefson, E. McAdam, S. L. Rolston, and M. K. Tubb. 1985. Excavation at the Pre-Pottery Neolithic B Village of ʿAin Ghazal, Jordan, 1983. *MDOG* 117: 69–115.

Rollefson, G. O., A. H. Simmons, and Z. Kafafi. 1992. Neolithic Cultures at ʿAin Ghazal. *Journal of Field Archaeology* 19: 443–70.

Rose, F. R. 2003. A Fresh Perspective: Isotopic Evidence for Prehistoric Human Subsistence in the Upper Mississippi River Valley of West-Central Illinois. Ph.D. dissertation, Rutgers University, New Brunswick, N.J.

Rose, J. C. 1980. *Bioarchaeology of Two Late Woodland sites, 22It537, 22Lo530, from the Tombigbee River Multi-Resource District, Mississippi.* Report to U.S. Army Corps of Engineers, Mobile District.

Rose, J. C., B. A. Burnett, M. B. Nassaney, and M. B. Blaueuer. 1984. Paleopathology at the Origins of Agriculture in the Lower Mississippi Valley and Caddoan Cultures. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 393–424. Orlando, Fla.: Academic Press.

Rose, J. C., M. K. Marks, and L. L. Tieszen. 1991. Bioarchaeology and Subsistence in the Central and Lower Portions of the Mississippi Valley. In *What Mean These Bones? Studies of Southeastern Bioarchaeology,* ed. M. L. Powell, P. S. Bridges, and A. M. W. Mires, 7–21. Tuscaloosa: University of Alabama Press.

Ross-Stallings, N. 1989. Treponemal Syndrome at the Austin Site (22Tu549): A Preliminary Report. *Mississippi Archaeology* 24: 1–16.

———. 1994. Elements of Biocultural Change in North Mississippi: Late Woodland

Through Contact. Paper presented at the annual meeting of the Southeastern Archaeological Conference, Lexington, Ky.

———. 1998. Observations of Treponematosis at the Austin and Barner Sites in Northwestern Mississippi. In *Results of Recent Archaeological Investigations in the Greater Mid-South,* ed. C. H. McNutt. Department of Anthropology Occasional Papers 18. Memphis, Tenn.: University of Memphis.

Rostworowski, M. 1972. Las Etnías del Valle del Chillón. *Revista del Museo Nacional* 35: 250–314.

———. 1993. *Ensayos de Historia Andina.* Lima: IEP/BCRP.

Roth-Lutra, K. H. 1967. Schädelserien des 5. Bis 2. Jahrtausend v.d. Z. In diskriminanzanalytischer Betrachtung. *Homo* 18 (3): 198–207.

Rowley-Conwy, P. 1985. The Origin of Agriculture in Denmark: A Review of Some Theories. *Journal of Danish Archaeology* 4: 188–95.

———. 2004. How the West Was Lost. *Current Anthropology* 45: 83–113.

Ruff, C. B. 1987. Post Cranial Adaptation to Subsistence Changes on the Georgia Coast. *American Journal of Physical Anthropology* 72 (2): 248.

———. 1992. Biomechanical Analyses of Archaeological Human Skeletal Samples. In *Skeletal Biology of Past Peoples,* ed. M. A. Saunders and A. Katzenberg, 37–58. New York: Wiley-Liss.

———. 1999. Skeletal Structure and Behavioral Patterns of Prehistoric Great Basin Populations. In *Understanding Prehistoric Lifeways in the Great Basin Wetlands: Bioarchaeological Reconstruction and Interpretation,* ed. B. E. Hemphill and C. S. Larsen, 290–320. Salt Lake City: University of Utah Press.

Ruff, C. B., and C. S. Larsen. 2001. Reconstructing Behavior in Spanish Florida: The Biomechanical Evidence. In *Bioarchaeology of Spanish Florida: The Impact of Colonialism,* ed. C. S. Larsen, 113–45. Gainesville: University Press of Florida.

Ruff, C. B., C. S. Larsen, and W. C. Hayes. 1984. Structural Changes in the Femur with the Transition to Agriculture on the Georgia Coast. *American Journal of Physical Anthropology* 64: 125–36.

Sadr, K. 2003. The Neolithic of Southern Africa. *Journal of African History* 44: 195–209.

Salles, J. F. 1996. Achaemenid and Hellenistic Trade in the Indian Ocean. In *The Indian Ocean in Antiquity,* ed. J. Read, 251–68. London: Kegan Paul International.

Salo, W., K. D. Eisenach, M. D. Cave, M. L. Beggs, G. L. Templeton, C. L. Thoen, and J. H. Bates. 1994. Identification of Mycobacterium Tuberculosis DNA in a Pre-Columbian Peruvian Mummy. *Proceedings of the National Academy of Science* 91: 2091–94.

Salvedi, L., F. Ricci, and G. Manzi. 2001. Porotic Hyperostosis as a Marker of Health and Nutritional Condition during Childhood: Studies of the Transition between Imperial Rome and the Early Middle Ages. *American Journal of Human Biology* 13 (6): 709–17.

Sandweiss, D. H. 1996. The Development of Fishing Specialization on the Central Andean Coast. In *Prehistoric Fishing Strategies,* ed. M. Plew, 41–63. Boise, Id.: Boise State University.

Sangvichien, S. R., V. Srisurin, and V. Watthanayingsakul. 1985. Estimation of Stature of Thai and Chinese from the Length of the Femur, Tibia and Fibula. *Siriraj Hospital Gazette* 37: 215–18.

Sangvichien, S., V. Srisurin, V. Wattanayinsakul, P. Theerarattakul, and S. Rakvanich-

pong. n.d. Equations for Estimation of Thai's Stature from the Length of Long Bones. Bangkok: Department of Anatomy, Faculty of Medicine, Siriraj Hospital, Mahidol University.

Sanlaville, P. 1992. Changements Climatiques dans la Péninsule Arabique durant le Pléistocène Supérieur et l'Holocène. *Paléorient* 18 (1): 5–26.

Santoro, C. M. 1980a. Estratigrafía y secuencia cultural funeraria fases Azapa, Alto Ramírez y Tiwanaku, Arica—Chile. *Chungara* 6: 24–45.

———. 1980b. Fase Azapa, transición del Arcaico al desarrollo Agrario Inicial en los valles bajos de Arica. *Chungara* 6: 46–56.

———. 1982. Formativo Temprano en el extremo norte de Chile. *Chungara* 8: 33–61.

———. 1989. Antiguos cazadores de la Puna 9.000 a 6.000 A.C. In *Culturas de Chile: Prehistoria, desde sus orígenes hasta la civilización,* ed. J. Hidalgo, V. Schiappacasse, H. Niemeyer, C. Aldunate, and S. Iván, 33–55. Santiago, Chile: Editorial Andrés Bello.

Sarie, I. 1995. Subsistence and Diet of Ain Ghazal Inhabitants as Inferred from the Analysis of Human Dentition. Unpublished M.A. thesis, Yarmouk University, Irbid, Jordan.

Sather, C. 1995. Sea Nomads and Rainforest Hunter-Gatherers: Foraging Adaptations in the Indo-Malaysian Archipelago. In *The Austronesians: Historical and Comparative Perspectives,* ed. P. Bellwood, J. J. Fox, and D. Tryon, 229–68. Canberra: Department of Anthropology, Research School of Pacific and Asian Studies, Australian National University.

Saul, F. P., and J. M. Saul. 1991. The Preclassic Population of Cuello. In *Cuello: An Early Maya Community in Belize,* ed. N. Hammond, 134–58. Cambridge, U.K.: Cambridge University Press.

Saul, J. M., and F. P. Saul. 1997. The Preclassic Skeletons from Cuello. In *Bones of the Maya,* ed. S. L. Whittington and D. M. Reed, 28–50. Washington, D.C.: Smithsonian Institution Press.

Saunders, S. R., and L. Barrans. 1999. What Can Be Done about the Infant Category in Skeletal Samples? In *Human Growth in the Past: Studies from Bones and Teeth,* ed. R. D. Hoppa and C. M. FitzGerald, 183–209. Cambridge, U.K.: Cambridge University Press.

Saunders, S. R., and R. D. Hoppa. 1993. Growth Deficits in Survivors and Non-survivors: Biological Mortality Bias in Subadult Skeletal Samples. *Yearbook of Physical Anthropology* 36: 127–51.

Saunders, S. R., and M. A. Katzenberg, eds. 1992. *Skeletal Biology of Past Peoples.* New York: Wiley-Liss.

Scarry, C. M. 1993. Botanical Remains. In *The Rock Levee Site: Late Marksville through Late Mississippi Settlement, Bolivar Co., Mississippi,* ed. R. A. Weinstein, R. S. Fuller, S. L. Scott, C. M. Scarry, and S. T. Duay. The Buelah Levee Project: Archaeology and History, vol. 3. Report submitted to U.S. Army Corps of Engineers, Vicksburg.

Schepartz, L. A. 1989. Modeling the Effects of Subsistence Pattern Change on Prehistoric Populations. In *People and Culture in Change,* ed. I. Hershkovitz, 199–219. BAR International Series 508. Oxford: British Archaeological Reports.

Schiappacasse, V., and H. Nimeyer. 1984. *Descripción y Análisis Interpretativo de un Sitio Arcaico Temprano en la Quebrada de Camarones*. Publicación Ocasional 41. Santiago, Chile: Museo Nacional de Historia Natural.

Schober, T. M. 1998. Reinvestigation of Maize Introduction in West-Central Illinois: A

Stable Isotope Analysis of Bone Collagen and Apatite Carbonate from Late Archaic to Mississippian Times. Master's thesis, University of Illinois at Urbana-Champaign.

Schoeninger, M. J., L. Sattenspiel, and M. R. Schurr. 1996. Transitions at Moundville. *American Journal of Physical Anthropology* supplement 22: 209.

Schoeninger, M. J., and M. R. Schurr. 1998. Human Subsistence at Moundville: The Stable Isotope Data. In *Archaeology of the Moundville Chiefdom,* ed. V. J. Knight Jr. and V. P. Steponaitis, 120–32. Washington, D.C.: Smithsonian Institution Press.

Schultz, M. 1987. Human Skeletal Remains. In *Report on the Excavations at Basta,* ed. H. J. Nissen, M. Muhsein, and H-G Gebel, 95–98. Amman: Annals of the Department of Antiquities of Jordan 35.

Schultz, M., C. S. Larsen, and K. Kreutz. 2001. Disease in Spanish Florida: Microscopy of Porotic Hyperostosis and Inferences about Health. In *Bioarchaeology of Spanish Florida: The Impact of Colonialism*, ed. C. S. Larsen, 207–225. Gainesville: University Press of Florida.

Schultz, M., and A. Sherer. 1991. The Human Skeletal Remains from Late PPNB Basta, Southern Jordan: a Preliminary Report on the Third Field Season. In Report on the Third Season of Excavations at Basta (1988), ed. H. J. Nissen, M. Muheisen, and H. G. Gebel. Annals of the Department of Antiquities of Jordan 32.

Schurr, M. R., and M. J. Schoeninger. 1995. Associations between Agricultural Intensification and Social Complexity: An Example from the Prehistoric Ohio Valley. *Journal of Anthropological Archaeology* 14: 315–99.

Schutkowski, H. 1987. Report on the Anthropological Activities during the 1987 Campaign at the Sites of Shimal and Dhayah, Ras al-Khaimah, U.A.E. Unpublished report, pp. 1–11; ms. in possession of author.

———. 1988. Report on the Anthropological Activities during the 1988 Campaign at the Sites of Shimal and Dhayah, Ras al-Khaimah, U.A.E. Unpublished report, pp. 7–10; ms. in possession of author.

Schutkowski, H., and B. Herrmann. 1987. Anthropological Report on Human Remains from the Cemetery at Shimal. In *Shimal 1985/6, Excavation of the German Archaeological Mission in Ras al-Khaimah, U.A.E.: A Preliminary Report,* ed. B. Vogt and U. Franke-Vogt, 55–65. Berliner Beiträge zum Vorderen Orient 8. Berlin.

Schwidetzky, I., and F. W. Rösing. 1989. Vergleichend-statistische Undersuchungen zur Anthropologie von Neolitikum und Bronzezeit. *Homo* 40 (1–2): 4–44.

Sciulli, P. W., and J. Oberly. 2002. Native Americans in Eastern North America: The Southern Great Lakes and Upper Ohio Valley. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 440–80. Cambridge, U.K.: Cambridge University Press.

Scott, E. C. 1979. Increase of Tooth Size in Prehistoric Coastal Peru, 10,000 BP–1,000 BP. *American Journal of Physical Anthropology* 50: 251–58.

Scott, G. T., and K. R. Parham. 1978. Analysis of the Human Osteological Remains. In *Excavations at the Tomotley Site (40MR5), Monroe County, Tennessee, 1973–1974,* ed. A. A. Guthe and M. E. Bistline, 123–66. Report of Investigations 24. Knoxville: Department of Anthropology, University of Tennessee.

Scott, S. 1983. Analysis, Synthesis, and Interpretation of Faunal Remains. In *Prehistoric Agricultural Communities in West Central Alabama,* vol. 2, ed. C. S. Peebles, 272–365. Report to U.S. Army Corps of Engineers, Mobile District, Mobile.

Scott, S., and C. J. Duncan. 1998. *Human Demography and Disease.* Cambridge, U.K.: Cambridge University Press.

Sealy, J., M. K. Patrick, A. G. Morris, and D. Alder. 1992. Diet and Dental Caries among Later Stone Age Inhabitants of the Cape Province, South Africa. *American Journal of Physical Anthropology* 88: 123–34.

Sealy, J., and S. Pfeiffer. 2000. Diet, Body Size and Landscape Use among Holocene Peoples in the Southern Cape, South Africa. *Current Anthropology* 41: 642–55.

Sealy, J., S. Pfeiffer, R. Yates, C. Willmore, A. Manhire, and T. Maggs. 2000. Hunter-Gatherer Child Burials from Pakhuis Mountains, Western Cape: Growth, Diet and Burial Practices in the Late Holocene. *South African Archaeological Bulletin* 55: 32–43.

Sealy, J., and N. J. van der Merwe. 1988. Social, Spatial and Chronological Patterning in Marine Food Use as Determined by ^{13}C Measurements of Holocene Human Skeletons from the South-Western Cape, South Africa. *World Archaeology* 20: 87–102.

Sears, E. O. 1982. Pollen Analysis. In *Fort Center: An Archaeological Site in the Lake Okeechobee Basin,* ed. W. H. Sears, 118–29. Gainesville: University Presses of Florida.

Seckler, D. V. 1980. Malnutrition: An Intellectual Odyssey. *Western Journal of Agricultural Economics* 5: 219–27.

Semino, O., G. Passarino, P. J. Oefner, A. A. Lin, S. Arbuzova, and L. E. Beckman. 2000. The Genetic Legacy of Paleolithic *Homo sapiens sapiens* in Extant Europeans: A Y-Chromosome Perspective. *Science* 290: 1155–59.

Sepúlveda, S. 1962. Regiones Geográficas de Chile. *Apartado de la Geografía Económica de Chile*, vol. 4. Santiago, Chile: CORFO.

Shady, R. S., J. Haas, and W. Creamer. 2001. Dating Caral, a Preceramic Site in the Supe Valley on the Central Coast of Peru. *Science* 292: 723–26.

Shao, W. 1984. The Yangshao Culture of the Middle Yellow River Valley. In *Xinzhongguo de Kaogu Faxian yu Yanjiu,* ed. Archaeological Institute of Chinese Academy of Social Sciences, 41–68. Beijing: Wenwu Press.

Shawky, R. M., and S. el Din. 1982. Iron Deficiency Anaemia in Children in Um al-Quwain, United Arab Emirates. *Journal of the Egyptian Society of Parasitology* 12 (1): 217–24.

Shi, J. 2001. Archaeology in China. *Acta Archaeologica* 72: 55–90.

Shields, B. M. 2003. An Analysis of the Archaic Human Burials at the Mulberry Creek (1CT27), Shell Mound, Colbert County, Alabama. M.A. thesis, Department of Anthropology, University of Alabama, Tuscaloosa.

Shigehara, N. 1994. Human Skeletal Remains from the Middle to Late Jomon Period Excavated from the Inland Kitamura Site, Nagano Prefecture. *Journal of Anthropological Science* 102 (4): 321–44.

Shinde, V. 1989. New Light on the Origin, Settlement System, and Decline of the Jorwe Culture of the Deccan, India. *South Asian Studies* 5: 59–72.

———. 1991. Craft Specialization and Social Organization in the Chalcolithic Deccan, India. *Antiquity* 65: 796–807.

———. 1994. The Deccan Chalcolithic: A Recent Perspective. *Man and Environment* 19 (1–2): 169–78.

Sieveking, G. G. 1954. Excavations at Gua Cha, Kelantan, 1954, Part I. *Federation Museums Journal* 1–2: 75–138.

Silva, A. M. 1996a. O Hipogeu de Monte Canelas I, IV–III Milénios A.C.: Estudo Paleobiológico da População Humana Exumada. Trabalho de Síntese. Provas de Aptidão Pedagógica e Capacidade Científica. Coimbra, Departamento de Antropologia da F.C.T.U.C. Not published.

———. 1996b. Paleobiology of the Population Inhumated in the Hipogeu of Monte Canelas I, Alcalar—Portugal. *XIII International Congress of Prehistoric and Protohistoric Sciences,* vol. 3, 437–46. Forlì, Italy, 8–14 September.

———. 1999. Human Remains from the Artificial Cave of São Pedro do Estoril II, Cascais, Portugal. *Human Evolution* 14 (3): 199–206.

———. 2002. Antropologia Funerária e PaleoBiologia das Populações Portuguesas Litorais do Neolítico Final/Calcolítico. Unpublished Ph.D. thesis, Coimbra, Departamento de Antropologia da F.C.T.U.C.

———. 2003a. Trepanation in the Portuguese Late Neolithic, Chalcolithic and Early Bronze Age Periods. In *Trepanation: History—Discovery—Theory,* ed. R. Arnott, S. Finger, and C. U. M. Smith, 117–29. Lisse: Swets and Zeitlinger.

———. 2003b. Portuguese Populations of the Late Neolithic and Chalcolithic Periods Exhumed from Collective Burials: An Overview. *Anthropologie* 41 (1–2): 55–64.

Simmons, A. H. 1997. Ecological Changes during the Late Neolithic in Jordan: A Case Study. In *The Prehistory of Jordan II: Perspectives from 1997,* ed. H. G. Gebel, Z. Kafafi, and G. O. Rollefson, 309–18. Berlin: Ex Oriente.

Simpson, S. W. 2001. Patterns of Growth Disruption in La Florida: Evidence from Enamel Microstructure. In *Bioarchaeology of Spanish Florida: The Impact of Colonialism,* ed. C. S. Larsen, 146–80. Gainesville: University Press of Florida.

Sims, D. C., M. E. Danforth, J. A. Giliberti, A. M. Montana, and T. McMakin. 1992. An Analysis of Diet in the Mississippian Population at Kellogg Village, Mississippi, Using Dental Indicators. *Mississippi Archaeology* 27: 45–59.

Sjøvold, T. 1990. Estimation of Stature from Long Bones Utilizing the Line of Organic Correlation. *Human Evolution* 5: 431–47.

Skinner, M. F. 1986. An Enigmatic Hypoplastic Defect of the Deciduous Canine. *American Journal of Physical Anthropology* 69 (1): 59–69.

Skinner, M. F., and A. H. Goodman. 1992. Anthropological Uses of Developmental Defects of Enamel. In *Skeletal Biology of Past Peoples,* ed. M. A. Saunders and A. Katzenberg, 153–74. New York: Wiley-Liss.

Sklar-Parnes, D. A., and P. Smith. 2003. The Human Remains from the Pottery Neolithic and Pre-Pottery Neolithic B Layers. In *The Neolithic Site of Abu Ghosh: The 1995 Excavations,* ed. H. Khalaily and O. Marder, 77–85. Israel Antiquities Authority Reports 19. Jerusalem.

Smith, A. G., C. Grigson, G. Hillman, and M. Tooley. 1981. The Neolithic. In *The Environment in British Prehistory,* ed. I. G. Simmons and M. Tooley, 125–209. London: Duckworth.

Smith, B. 1975. *Middle Mississippian Exploitation of Animal Populations.* Anthropological Papers of the Museum of Anthropology 57. Ann Arbor: University of Michigan.

Smith, B. H. 1984. Patterns of Molar Wear in Hunter Gatherers and Agriculturalists. *American Journal of Physical Anthropology* 63: 39–56.

———. 1991. Standards of Human Tooth Formation and Dental Age Assessment. In *Advances in Dental Anthropology,* ed. M. A. Kelley and C. S. Larsen, 143–68. New York: Wiley Liss.

Smith, C. 1992. *Late Stone Age Hunters of the British Isles*. London: Routledge.

Smith, F. H., M. O. Smith, and R. J. Hinton. 1980. Evolution of Tooth Size in the Prehistoric Inhabitants of the Tennessee Valley. Tennessee Anthropological Association *Miscellaneous Papers No. 5,* pp. 81–103, Knoxville.

Smith, M. O. 1983. Patterns of Association between Oral Health Status and Subsistence: A Study of Aboriginal Skeletal Populations from the Tennessee Valley Area. Ph.D. thesis, Department of Anthropology, University of Tennessee, Knoxville.

———. 1996. Biocultural Inquiry into Archaic Period Populations of the Southeast: Trauma and Occupational Stress. In *Archaeology of the Mid-Holocene Southeast,* ed. K. E. Sassaman and D. G. Anderson, 134–56. Gainesville: University Press of Florida.

———. 1997. Osteological Indications of Warfare in the Archaic Period of the Western Tennessee Valley. In *Troubled Times: Violence and Warfare in the Past,* ed. D. L. Martin and D. W. Frayer, 241–265. Amsterdam: Gordon and Breach.

———. 2003. Beyond Palisades: The Nature and Frequency of Late Prehistoric Deliberate Violent Trauma in the Chickamauga Reservoir of East Tennessee. *American Journal of Physical Anthropology* 121 (4): 303–18.

Smith, P. 1972. Diet and Attrition in the Natufians. *American Journal of Physical Anthropology* 37: 233–38.

———. 1991. The Dental Evidence for Nutritional Status in the Natufians. In *The Natufian Culture in the Levant,* ed. O. Bar-Yosef and F. R. Valla, 425–34. International Monographs in Prehistory, Archaeology Series 1. Ann Arbor, Mich.

———. 1995. People of the Holy Land from Prehistory to the Recent Past. In *The Archaeology of Society in the Holy Land,* ed. T. E. Levy, 58–75. London: Leicester University Press.

Smith, P., O. Bar-Yosef, and A. Sillen. 1984. Archaeological and Skeletal Evidence for Dietary Change during the Late Pleistocene/Early Holocene in the Levant. In *Paleopathology at the Origins of Agriculture,* ed. M. N. Cohen and G. J. Armelagos, 101–36. Orlando, Fla.: Academic Press.

Smith, P., and L. K. Horwitz. 1998. Culture, Environment and Disease: Paleo-Anthropological Findings for the Southern Levant. In *Archaeology of Emerging Diseases,* ed. C. Greenblatt and I. Cohen, 201–40. Rehovot, Israel: Balaban Publishers.

Smith, P., L. K. Horwitz, and E. Kaplan. 1992. Skeletal Evidence for Population Change in the Late Holocene of the South-Western Cape: A Radiological Study. *South African Archaeological Bulletin* 47: 82–88.

Smith, P., and B. Peretz. 1986. Hypoplasia and Health Status: A Comparison of Two Lifestyles. *Human Evolution* 1: 535–44.

Smith, P., and J. Verdene. 1994. The Dentition of the PPNA Specimens. In *Le site de Hatoula en judee occidentale, Israel,* ed. M. Lechevallier and A. Ronen, 73–79. Mémoires et Travaux du Centre de Recherches Préhistoriques Français de Jérusalem. Paris: Association Paléorient.

Smith, R. 2003. The Analysis of Skeletal Fractures from Windover (8BR246) and Their Inference Regarding Lifestyle. Master's thesis, Florida State University, Tallahassee.

Sobolik, K. D. 1994. *Paleonutrition: The Diet and Health of Prehistoric Americans*. Carbondale: Southern Illinois University Press. Occasional Paper Series no 22.

———. 2000. Dietary Reconstruction as Seen in Coprolites. In *The Cambridge World History of Food,* ed. K. Kiple and K. C. Ornelas, 51–57. Cambridge, U.K.: Cambridge University Press.

Soliveres, O. 1978. Les restes post-cephaliques. In *Abou Ghosh et Beisamoun deux gisements du VIIe millenaire avant l'ere chretienne en Israel,* ed. M. Lechevallier, 181–92. Mémoires et Travaux du Centre de Recherches Préhistoriques Français de Jérusalem 2. Paris: Association Paléorient.

Sornmani, S., P. Vivatanasesth, P. Impand, W. Phatihatakorn, and P. Sitabutra. 1984. Infection and Re-infection Rates of Opisthorchiasis in the Water Resource Development Area of Nam Pong Project, Khon Kaen Province, Northeast Thailand. *Annals of Tropical Medicine and Parasitology* 78: 649–56.

Spriggs, M. 1989. The Dating of the Island Southeast Asian Neolithic: An Attempt at Chronometric Hygiene and Linguistic Correlation. *Antiquity* 63: 587–613.

———. 1996. Chronology and Colonisation in Island Southeast Asia and the Pacific: New Data and an Evaluation. In *Oceanic Culture History: Essays in Honour of Roger Green,* ed. J. Davidson, G. Irwin, B. F. Leach, A. Pawley, and D. Brown, 33–50. Dunedin: New Zealand Journal of Archaeology.

Standen, V. G. 1991. El Cementerio Morro-1: Nuevas Evidencias de la Tradición Funeraria Chinchorro, Periodo Arcaico, Norte de Chile. Master's thesis, Pontificia Universidad Católica del Perú.

———. 1997. Temprana Complejidad Funeraria de la Cultura Chinchorro, Norte de Chile. *Latin American Antiquity* 8: 134–56.

———. 2004. Patrón Funerario Arcaico Temprano del Sitio Acha-3 y su Relación con Chinchorro: Cazadores, Pescadores y Recolectores de la Costa Norte de Chile. *Latin American Antiquity* 15: 89–109.

Stanton, J. 2001. Listening to the Ga: Cicely Williams' Discovery of Kwashiorkor on the Gold Coast. *Clio Medica* 61: 149–71.

Steadman, D. W. 2001. Mississippians in Motion? A Population Genetic Analysis of Interregional Gene Flow in West-Central Illinois. *American Journal of Physical Anthropology* 114 (1): 61–73.

Steckel, R. H. 1995. Stature and the Standard of Living. *Journal of Economic Literature* 33: 1903–40.

———. 2005. Young Adult Mortality Following Severe Physical Stress in Childhood: Skeletal Evidence. *Economics and Human Biology* 3: 14–28.

Steckel, R. H., and J. M. Prince. 2001. Tallest in the World: Native Americans of the Great Plains in the Nineteenth Century. *American Economic Review* 91: 287–94.

Steckel, R. H., and J. C. Rose, ed. 2002a. *The Backbone of History.* Cambridge, U.K.: Cambridge University Press.

———. 2002b. Patterns of Health in the Western Hemisphere. In *The Backbone of History,* ed. R. H Steckel and J. C. Rose, 563–82. Cambridge, U.K.: Cambridge University Press.

Steckel, R. H., P. W. Sculli, and J. C. Rose. 2002. A Health Index from Skeletal Remains. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 61–93. Cambridge, U.K.: Cambridge University Press.

Steel, R. G. D., and J. H. Torrie. 1988. *Bioestadística: Principios y Procedimientos.* Mexico City: McGraw-Hill.

Steele, D. G., and C. A. Bramblett. 1988. *The Anatomy and Biology of the Human Skeleton.* College Station: Texas A&M University Press.

Stefanescu, G., J. Hatina, M. Belledi, A. D. Rienzo, A. Novelletto, A. Oppenheim, S. Nørby, and others. 2000. Tracing European Founder Lineages in the Near Eastern mtDNA Pool. *American Journal of Human Genetics* 67: 1251–76.

Steffensen, J. 1969. Thaettir úr Líffraedi Íslendinga. *Laeknaneminn* 22: 5–18.

Steyn, M. 1997. A Reassessment of the Human Skeletons from K2 and Mapungubwe, South Africa. *South African Archaeological Bulletin* 52: 14–20.

Steyn, M., and M. Henneberg. 1995. Pre-Columbian Presence of Treponemal Dis-

ease: A Possible Case from Iron Age Southern Africa. *Current Anthropology* 36: 869–73.

Stiner, M. C., and N. D. Monroe. 2002. Approaches to Prehistoric Diet Breadth, Demography, and Prey Ranking Systems in Time and Space. *Journal of Archaeological Method and Theory* 9: 181–214.

Stini, W. A. 1985. Growth Rates and Sexual Dimorphism in Evolutionary Perspectives. In *The Analysis of Prehistoric Diets,* ed. R. I. Gilbert and J. H. Mielke, 191–226. Orlando, Fla.: Academic Press.

Stock, J., and S. K. Pfeiffer. 2001. Linking Structural Variability in Long Bone Diaphyses to Habitual Behaviors: Foragers from the Southern African Later Stone Age and the Andaman Islands. *American Journal of Physical Anthropology* 115: 337–48.

———. 2004. Long Bone Robusticity and Subsistence Behaviour among Later Stone Age Foragers of the Forest and Fynbos Biomes of South Africa. *Journal of Archaeological Science* 31: 99–103.

Stodder, A. L. W., D. L. Martin, A. H. Goodman, and D. T. Reff. 2002. Cultural Longevity and Biological Stress in the American Southwest. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 481–505. Cambridge, U.K.: Cambridge University Press.

Stone, P. 1996. Bioarchaeological Analysis of a 1st Century AD Collective Tomb from the Ed Dur Site, United Arab Emirates. M.A. thesis, University of Massachusetts, Amherst.

Stone, P. K., and D. L. Martin. Forthcoming. Human Skeletal Remains. In *Excavations at Jabal al-Emaleh: A Third Millennium Site in the Emirate of Sharjah,* ed. J. Benton. Turnhout: Brepols.

Storey, R., and L. Márquez Morfín. 2003. Deeper Implications of Mesoamerican/Maya Populations in the "Backbone of History" Health Index. Paper presented at the International Congress of Anthropological and Ethnological Sciences, Florence, Italy, July.

Stothert, K. E. 1980. The Villa Salvador Site and the Beginning of the Early Intermediate Period in the Lurín Valley, Peru. *Journal of Field Archaeology* 7: 279–95.

Stothert, K. E., and R. Ravines. 1977. Investigaciones Arqueologicas en Villa El Salvador. *Revista del Museo Nacional* 43: 157–226.

Strassman, B. I., and R. I. M. Dunbar. 1999. Human Evolution and Disease: Putting the Stone Age in Perspective. In *Evolution in Health and Disease,* ed. S. C. Stearns, 91–100. Oxford, U.K.: Oxford University Press.

Strongman, S. R. 1994. Report on the Findings from the Analysis of the Human Skeletal Remains Excavated in 1993 from Site 2, Umm al-Qaiwain, United Arab Emirates. Unpublished report, pp. 1–19; ms. in possession of author.

Strouhal, E. 1974. Five Plastered Skulls from Pre-Pottery Neolithic B, Jericho. *Paléorient* 1: 231–47.

Stuart-Macadam, P. 1987a. A Radiographic Study of Porotic Hyperostosis. *American Journal of Physical Anthropology* 74: 511–20.

———. 1987b. Porotic Hyperostosis: New Evidence to Support the Anemia Theory. *American Journal of Physical Anthropology* 74: 521–26.

———. 1989. Porotic Hyperostosis: Relationship between Orbital and Vault Lesions. *American Journal of Physical Anthropology* 80: 187–93.

———. 1991. Porotic Hyperostosis: Changing Interpretations. In *Human Paleopathology,* ed. D. J. Ortner and A. C. Aufderheide, 36–54. Washington, D.C.: Smithsonian Institution Press.

———. 1992a. Cranial Thickening and Anemia: Reply to Dr. Webb. *American Journal of Physical Anthropology* 88: 109–10.

———. 1992b. Anemia in Past Human Populations. In *Diet, Demography and Disease: Changing Perspectives on Anemia,* ed. P. Stuart-Macadam and S. K. Kent, 151–70. New York: Aldine.

———. 1992c. Porotic Hyperostosis: A New Perspective. *American Journal of Physical Anthropology* 87: 39–47.

Studenmund, S. 2000. Late Woodland Occupations in the Lower Illinois Valley: Research Questions and Data Sets. In *Late Woodland Societies: Tradition and Transformation across the Midcontinent,* ed. T. E. Emerson, D. L. McElrath, and A. C. Fortier, 301–44. Lincoln: University of Nebraska Press.

Su, B. 1999. *New Research on the Origins of Chinese Civilization.* Beijing: Sanlian Press.

Sukhbaatar, G. 1971. *Sayanbi Nariin Ugsaa Garal, Soyal.* (The Background and Culture of Sayanbi Populations.) Ulaanbaatar, Mongolia: Printing House MAS.

———. 1980. *Mongolchuudiin ertnii Eveg.* (The Ancestors of Mongols.) Ulaanbaatar, Mongolia: Academic Press.

Sutter, R. 1997. Dental Variation and Biocultural Affinities among Prehistoric Populations from Coastal Valleys of Moquehua, Perú, and Azapa, Chile. Ph.D. dissertation, University of Missouri–Columbia.

———. 2000. Prehistoric Genetic and Culture Change: A Bioarchaeological Search for the Pre-Inka Altiplano Colonies in the Coastal Valleys of Moquehua, Peru, and Azapa, Chile. *Latin American Antiquity* 11: 43–70.

———. 2005. The Prehistoric Peopling of South America as Inferred from Epigenetic Dental Traits. *Andean Past* 7: 183–217.

Sutter, R., and L. Mertz. 2004. Nonmetric Cranial Trait Variation and Prehistoric Biocultural Change in the Azapa Valley, Chile. *American Journal of Physical Anthropology* 123: 130–45.

Suzuki, T. 1991. Paleopathological Study in Infectious Diseases in Japan. In *Human Paleopathology,* ed. D. J. Ortner and A. C. Aufderheide, 128–40. Washington, D.C.: Smithsonian Institution Press.

Suzuki, T., M. Takayuki, and Han Kangxin. 2005. On the Possible Case of Treponematosis from the Bronze Age in China. *Journal of Anthropological Science* 113: 253–58.

Swedlund, A. C., and G. J. Armelagos, eds. 1990. *Disease in Populations in Transition.* New York: Bergin and Garvey.

Tanner, J. M. 1978. *Foetus into Man: Physical Growth from Conception to Maturity.* Cambridge, Mass.: Harvard University Press.

Tattersall, I. 1985. The Human Skeletons from Huaca Prieta, with a Note on Exostoses of the External Auditory Meatus. In *The Preceramic Excavations at the Huaca Prieta, Chicama Valley, Peru,* ed. J. B. Bird and J. Hyslop, 59–74. Anthropological Papers of the American Museum of Natural History 62. New York.

Tauber, H. 1986. Analysis of Stable Isotopes in Prehistoric Populations. In *Innovative Trends in Prehistoric Anthropology,* ed. B. Hermann, 31–38. Mitteilungen der Berliner Gesellschaft für Antropologie, Etnologie und Urgeschichte 7. Berlin.

Tayles, N. 1999. *The Excavation of Khok Phanom Di, a Prehistoric Site in Central Thai-*

land, vol. 5, *The People.* Research Report 61. London: Society of Antiquaries of London.

Tayles, N., and H. R. Buckley. 2004. Leprosy and Tuberculosis in Iron Age Southeast Asia. *American Journal of Physical Anthropology* 125 (3): 239–56.

Tayles, N., K. Domett, and K. Nelsen. 2000. Agriculture and Dental Caries: The Case of Rice in Prehistoric Southeast Asia. *World Archaeology* 32: 68–83.

Tayles, N., K. Nelson, H. Buckley, and K. Domett. 1998. The Iron-Age People of Noen U-Loke, Northeast Thailand: A Preliminary Review of the First Two Field Seasons. *Bulletin of the Indo-Pacific Prehistory Association* 17: 75.

Taylor, L. H., S. M. Latham, and M. E. J. Woolhouse. 2001. Risk Factors for Human Disease Emergence. *Philosophical Transactions of the Royal Society of London Bulletin* 356: 983–89.

Tchernov, E., and F. Valla. 1997. Two New Dogs and Other Natufian Dogs from the Southern Levant. *Journal of Archaeological Science* 24: 65–95.

Teaford, M. F. 1991. Dental Microwear: What Can It Tell Us about Diet and Dental Function? In *Advances in Dental Anthropology,* ed. M. A. Kelley and C. S. Larsen, 342–56. New York: Wiley-Liss.

———. 2002. Dental Enamel Microwear Analysis. In *Foraging, Farming, and Coastal Biocultural Adaptation in Late Prehistoric North Carolina,* ed. D. L. Hutchinson, 169–77. Gainesville: University Press of Florida.

Teaford, M. F., C. S. Larsen, R. F. Pastor, and V. E. Noble. 2001. Pits and Scratches: Microscopic Evidence of Tooth Use and Masticatory Behavior in La Florida. In *Bioarchaeology of Spanish Florida: The Impact of Colonialism,* ed. C. S. Larsen, 82–112. Gainesville: University Press of Florida.

Teaford, M. F., and J. D. Lytle. 1996. Brief Communication: Diet Induced Changes in Rates of Human Tooth Microwear: A Case Study Involving Stone-Ground Maize. *American Journal of Physical Anthropology* 100: 143–47.

Thomas, D. H. 1986. *Refiguring Anthropology: First Principles of Probability and Statistics.* Prospect Heights, Ill.: Waveland Press.

Thosarat, R. 2000. The Fish Remains. In *Noen U-Loke, Report to the Fine Arts Department, Thailand*, ed. C. F. W. Higham and R. Thosarat, 213–17. Dunedin, New Zealand: University of Otago.

Toledo, X., and E. Zapater. 1991. *Geografía General y Regional de Chile.* Santiago, Chile: Editorial Universitaria.

Tosi, M. 1975. Notes on the Distribution and Exploitation of Natural Resources in Ancient Oman. *Journal of Oman Studies* 1: 187–206.

———. 1986. The Emerging Picture of Prehistoric Arabia. *Annual Review of Anthropology* 15: 461–90.

Tot, A., and B. Firshtein. 1971. *Anthropologicheskii dannie k voprosy o velikom pereselenii narodov: Avarii I Sarmatii.* (Anthropological Data on the Great Migration of Nationalities: Avarii I Sarmatii.) Leningrad: Izdateljstvo-Leningrad-Skogo-Universiteta.

Townsend, G., P. Dempsey, T. Brown, J. Kaidonis, and L. Richard. 1994. Teeth, Genes, and the Environment. *Perspectives on Human Biology* 4: 35–46.

Trisi, G. n.d. A Reanalysis of the Lake George Skeletal Population. Dissertation in progress, Department of Anthropology, Tulane University, New Orleans.

Tristan, M., et al. 1982. Evolucion de la Tall, 1979–1981. *Revista Medica del Hospital Nacional de Ninos* 17: 285–96.

Trotter, M. 1970. Estimation of Stature from Intact Long Limb Bones. In *Personal Identification in Mass Disasters,* ed. T. D. Stewart, 71–83. Washington, D.C.: Smithsonian Institution Press.

Trotter, M., and G. C. Gleser. 1952. Estimation of Stature from Long Bones of American Whites and Negroes. *American Journal of Physical Anthropology* 10: 463–514.

———. 1959. A Re-evaluation of Estimation of Stature Based on Measurements of Stature Taken during Life and Long Bones after Death. *American Journal of Physical Anthropology* 16: 79–123.

Truswell, A. S., and J. D. L. Hanson. 1976. Medical Research among the !Kung. In *Kalahari Hunter-Gatherers,* ed. R. B. Lee and I. DeVore, 166–94. Cambridge, Mass.: Harvard University Press.

Tsegmed, S. H. 1969. *Mongoliin phizik gazar zui.* (The Mongolian Physical Geography.) Ulaanbaatar, Mongolia: Printing House Erdem.

Tseveendorj, D. 1978. *Chandmanskii kul'tura.* (Culture of Chandman: Archaeology and Ethnography of Mongolia.) Novosibirsk, Siberia: Russian Academy of Sciences.

Turbat, Ts., Ch. Amartuvshin, and U. Erdenebat. 2003. *Archaeological Monuments of Egiin Gol Valley (From Bronze Age to Mongolian Period)*, ed. D. Tseveendorj. Ulaanbaatar, Mongolia: Soyombo Printing House.

Turner, C. G., II. 1979. Dental Anthropological Indications of Agriculture among the Jomon of Central Japan. *American Journal of Physical Anthropology* 51: 619–36.

Tuross, N., M. L. Fogel, L. Newsom, and G. H. Doran. 1994. Subsistence in the Florida Archaic: The Stable-Isotope and Archaeobotanical Evidence from the Windover Site. *American Antiquity* 59: 288–303.

Tykot, R. H., R. L. Burger, and N. J. van der Merwe. 2006. The Importance of Maize in the Initial Period and Early Horizon Peru. In *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*, ed. J. Staller, R. H. Tykot, and B. Benze, 187–98. New York: Academic Press.

Ubelaker, D. H. 1989. *Human Skeletal Remains.* Washington, D.C.: Taraxacum.

———. 1990. Porotic Hyperostosis, Parasitism and Sedentism in Ancient Ecuador. *American Journal of Physical Anthropology* 81 (2): 309–10.

———. 1992. Enamel Hypoplasia in Ancient Ecuador. In *Recent Contributions to the Study of Enamel Developmental Defects*, ed. A. H. Goodman and L. Capasso, 207–17. *Journal of Paleopathology* Monographic Publication 2, Chiete, Italy.

Ubelaker, D. H., and L. A. Newson. 2002. Patterns of Health and Nutrition in Prehistoric and Historic Ecuador. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 343–75. Cambridge, U.K.: Cambridge University Press.

Uerpmann, M. 2003. The Dark Millennium—Remarks on the Final Stone Age in the Emirates and Oman. In *Archaeology of the United Arab Emirates,* ed. D. Potts, H. Al Naboodah, and P. Hellyer, 74–81. Proceedings of the First International Conference on the Archaeology of the U.A.E. London: Trident Press.

Uerpmann, M., H. Uerpmann, and S. A. Jasim. 2000. Stone Age Nomadism in SE-Arabia—Palaeo-Economic Considerations on the Neolithic Site of Al-Buhais 18 in the Emirate of Sharjah, UAE. *Proceedings of the Seminar on Arabian Studies* 30: 229–34.

Underhill, A. P. 1989. Warfare during the Chinese Neolithic Period: A Review of the

Evidence. In *Cultures in Conflict: Current Archaeological Perspectives,* ed. D. C. Tkaczuk and B. C. Vivian, 229–41. Calgary: University of Calgary Archaeological Association.

USAID. 1999a. Food Commodity Fact Sheets: Corn. <http://www.usaid.gov/hum_response/crg/fscorn.htm>.

———. 1999b. Food Commodity Fact Sheets: Wheat. <http://www.usaid.gov/hum_response/crg/fswheat.htm>.

Valla, F. 1995. The First Settled Societies—Natufian (12,000–10,200 BC). In *The Archaeology of Society in the Holy Land,* ed. T. E. Levy, 169–87. London: Leicester University Press.

Valla, F. R., H. Khalaily, N. Samulian, R. March, F. Bocquentin, B. Valentin, O. Marder, R. Rabinovich, G. Le Dosseur, L. Dubreuil, and A. Belfer-Cohen. 2001. Le Natoufien final de Mallaha (Eynan), deuxièume rapport préliminaire: Les fouilles de 1998 à 1999. *Journal of the Israel Prehistorical Society* 31: 43–184.

van der Merwe, N. J., and E. Medina. 1989. Photosynthesis and $^{13}C/^{12}C$ Ratios in Amazonian Rain Forests. *Geochimica et Cosmochemica Acta* 53: 1091–94.

———. 1991. The Canopy Effect, Carbon Isotope Ratios and Foodwebs in Amazonia. *Journal of Archaeological Science* 18: 249–59.

van der Merwe, N. J., and J. C. Vogel. 1978. C Content of Human Collagen as a Measure of Prehistoric Diet in Woodland North America. *Nature* 276: 815–16.

Van Derwarker, A. M. 1999. Feasting and Status at the Toqua Site. *Southeastern Archaeology* 18: 24–34.

Van Reenen, J. F. 1966. Dental Features of a Low-caries Primitive Population. *Journal of Dental Research* 45: 703–13.

Van Valen, L. 1962. A Study of Fluctuating Asymmetry. *Evolution* 16: 125–42.

Vargas, L. A. 1990. Old and New Transitions and Nutrition in Mexico. In *Disease in Populations in Transition,* ed. A. C. Swedlund and G. J. Armelagos, 145–60. New York: Bergin and Garvey.

Vasquez, S. 1984. *La Waka Pucllana.* Gaceta Arqueológica Andina N. 9. Lima, Peru: Instituto de Estudios Arqueológicos.

Verano, J. W. 1992. Prehistoric Disease and Demography in the Andes. In *Disease and Demography in the Americas,* ed. J. W. Verano and D. H. Ubelaker, 15–24. Washington, D.C.: Smithsonian Institution Press.

Verano, J. W., and D. H. Ubelaker, eds. 1992. *Disease and Demography in the Americas.* Washington, D.C.: Smithsonian Institution Press.

Vince, A. 1989. Saxon Urban Economies: An Archaeological Perspective. In *Environment and Economy in Anglo-Saxon England,* ed. J. Rackham, 108–19. Council for British Archaeology Research Report 89. York, U.K.

Virchow, R. 1870. Die Altnordischen Schädel zu Kopenhagen. *Archiv für Anthropologie* 4: 55–91.

Voelker, J. 2002. From Site Specific to Regional Synthesis: Using Ceramics to Bridge the Gap. Paper presented at the 17th Indo-Pacific Prehistory Association Congress.

Vogt, B., J. Häser, J-M. Kästner, H. Schutkowski, and C. Velde. 1989. Preliminary Remarks on Two Recently Excavated Tombs in Shimal, Ras al-Khaimah, United Arab Emirates. In *South Asian Archaeology,* ed. K. Frifelt and P. Sørensen, 62–73. London: Curzon Press.

Volkov, V. V. 1972. *Expedition in Mongolia.* Russia: A. O. Moscow.

Volkov, V. V. 1974. Ulangomskii Mogilinik i Nekotorie Voprosi Ethnicheskoi Istoriii

Mongolii (Ulanngom Burials and Some Questions on Ethnical History of Mongoli). Roli Kochevikh Naradov v Tsivilizatsii Tsentralnoi Asii (The Roles of Nomads in the Civilization of Central Asia). Ulaanbaastar: Printing house of the Academic Press.

Vradenburg, J. A. 2001. The Role of Treponematoses in the Development of Prehistoric Cultures and the Bioarchaeology of Proto-urbanism on the Central Coast of Peru. Ph.D. dissertation, University of Missouri–Columbia.

Vradenburg, J. A., R. A. Benfer Jr., and L. Sattenspiel. 1997. Evaluating Archaeological Hypotheses of Population Growth and Decline on the Central Coast of Peru. In *Integrating Archaeological Demography,* ed. R. R. Paine, 150–72. Center for Archaeological Investigations, Southern Illinois University at Carbondale, Occasional Paper 24.

Wacher, J. 2000. *A Portrait of Roman Britain.* London: Routledge.

Wadley, L. 1987. Later Stone Age Hunters and Gatherers of the Southern Transvaal: Social and Ecological Interpretation. Oxford: British Archaeological Reports.

———. 1998. The Invisible Meat Providers: Women in the Stone Age of South Africa. In *Gender in African Prehistory*, ed. S. Kent, 69–82. Walnut Creek, Calif.: Altamira Press.

Waldron, T. 1989. The Effects of Urbanization on Human Health: The Evidence from Skeletal Remains. In *Diet and Crafts in Towns: The Evidence of Animal Remains from the Roman to the Post-Medieval Period,* ed. D. Sergeantson and T. Waldron, 55–73. BAR British Series 199. Oxford: Oxford University Press.

———. 1994. *Counting the Dead.* Chichester: John Wiley and Sons.

Walker, P. L. 1986. Porotic Hyperostosis in a Marine-Dependent California Indian Population. *American Journal of Physical Anthropology* 69: 345–54.

———. 1989. Cranial Injuries as Evidence of Violence in Prehistoric Southern California. *American Journal of Physical Anthropology* 80: 313–23.

———. 2005. A Paleopathological Perspective on the Evolution of Coastal Adaptation in the Western Hemisphere. Paper presented at Paminsa: Conference of the Paleopathology Association. Rio de Janeiro.

Walker, P. L., D. C. Cook, and P. M. Lambert. 1997. Skeletal Evidence for Child Abuse: A Physical Anthropological Perspective. *Journal of Forensic Science* 42: 196–207.

Walker, P. L., and R. Thornton. 2002. Health, Nutrition and Demographic Change in Native California. In *The Backbone of History,* ed. R. H. Steckel and J. C. Rose, 524–63. Cambridge, U.K.: Cambridge University Press.

Wall, J. R. D. 1967. The Quaternary Geomorphological History of North Sarawak with Special Reference to the Subis Karst, Niah. *Sarawak Museum Journal* 15: 97–125.

Wang, J. 1985. Earlier Agriculture in Henan Province and Surroundings According to Peiligang Site Tools. *Nongye Kaogu* 2: 81–85.

Wang, X. G. 1998. On Overlapping Millet and Rice Regions in Neolithic China. *Nongye Kaogu* 1: 400.

Wapler, U., E. Crubézy, and M. Schultz. 2004. Cribra Orbitalia Synonymous with Anemia? Analysis and Interpretation of Cranial Pathology in Sudan. *American Journal of Physical Anthropology* 123: 333–39.

Ward, J. W. 1972. A Comparative Study of the Arnold and Ganier Populations Based on Osteological Observations. In *The Middle Cumberland Culture,* ed. R. B. Ferguson. Publications in Anthropology 3. Nashville, Tenn.: Vanderbilt University.

Webb, S. 1995. *Palaeopathology of Aboriginal Australians: Health and Disease across a Hunter-Gatherer Continent.* Cambridge, U.K.: Cambridge University Press.

Webb, S. G., and P. C. Edwards. 2002. The Natufian Human Skeletal Remains from Wadi Hammeh 27, Jordan. *Paléorient* 28: 103–24.

Wei, X., Zhaochen Kong, and Changjiang Liu. 2001. The Finding and Importance of Rice Remains from the Yangshao Cultural Site of Nanjiakou in Sanmenxian. *Nongye Kaogu* 3: 77–79.

Weir, G. H., R. A. Benfer, and J. G. Jones. 1988. Preceramic to Early Formative Subsistence on the Central Coast. In *Economic Prehistory of the Central Andes,* ed. E. S. Wing and J. C. C. Wheeler, 56–94. BAR International Series 427. Oxford: British Archaeological Reports.

Weiss, K. M. 1973. *Demographic Models for Anthropology.* Society for American Anthropology Memoir 27. Washington, D.C.

Weiss, R. A. 2001. The Leeuwenhoek Lecture 2001: Animal Origins of Human Infectious Disease. *Philosophical Transactions of the Royal Society of London Bulletin* 356: 957–77.

Welch, D. J. 1985. Adaption to Environmental Unpredictability: Intensive Agriculture and Regional Exchange at Late Prehistoric Centres in the Phimai Region in Thailand. Ph.D. dissertation, University of Hawai'i, Manoa.

Welch, M. 1992. *Anglo-Saxon England.* London: Batsford/English Heritage.

Wells, C. 1984. Human Bone. In Prehistoric Tombs of Ras al-Khaimah, ed. P. Donaldson. *Oriens Antiquus* 23 (3–4): 213–18, 268–72, 277–79.

———. 1985. Human Bone. In Prehistoric Tombs of Ras al-Khaimah, ed. P. Donaldson. *Oriens Antiquus* 24: 87–90.

Wendt, W. S. 1963. Die Prakeramische Siedlung am Rio Seco, Peru. *Baessler Archiv, Neue Folge* 11. 2:225–275

White, C. 1990. Patterns of Anemia and Diet before and after the Conquest of the Maya. *American Journal of Physical Anthropology* 83 (2): 69.

———. 1997. Ancient Diet at Lamanai and Pacbitun: Implications for the Ecological Model of Collapse. In *Bones of the Maya,* ed. S. L. Whittington and D. M. Reed, 171–80. Washington, D.C.: Smithsonian Institution Press.

White, J. C. 1985. Incorporating Heterarchy into Theory on Sociopolitical Development: The Case from Southeast Asia. In *Heterarchy and the Analysis of Complex Societies,* ed. R. M. Ehrenreich, C. L. Crumley, and J. E. Levy, 101–23. Arlington, Va.: American Anthropological Association.

———. 1986. A Revision of the Chronology of Ban Chiang and Its Implications for the Prehistory of Northeast Thailand. Ph.D. dissertation, University of Pennsylvania, Philadelphia. Ann Arbor, Mich.: University Microfilms.

———. 1995. Modeling the Development of Early Rice Agriculture: Ethnoecological Perspectives from Northeast Thailand. *Asian Perspectives* 34 (1): 37–68.

White, J. C., D. Penny, L. Kealhofer, and B. Maloney. 2004. Vegetation Changes from the Late Pleistocene through the Holocene from Three Areas of Archaeological Significance in Thailand. *Quaternary International* 113: 111–32.

White, W. A. 1970. *The Geomorphology of the Florida Peninsula.* State of Florida Department of Natural Resources, Geological Bulletin 51. Tallahassee.

Whittington, S. L., and D. M. Reed, ed. 1997. *Bones of the Maya.* Washington, D.C.: Smithsonian Institution Press.

Whittle, A. 1999. The Neolithic Period. In *The Archaeology of Britain: An Introduction from the Upper Palaeolithic to the Industrial Revolution,* ed. J. R. Hunter and I. Ralston, 58–76. London: Routledge.

Whyte, I. 1999. The Historical Geography of Britain from AD 1500: Landscape and Townscape. In *The Archaeology of Britain: An Introduction from the Upper Palaeolithic to the Industrial Revolution,* ed. J. R. Hunter and I. Ralston, 264–79. London: Routledge.

Wilcox, G., and M. Tengberg. 1995. Preliminary Report on the Archaeobotanical Investigations at Tell Abraq with Special Attention to Chaff Impressions in Mud Brick. *Arabian Archaeology and Epigraphy* 6: 129–38.

Wilen, R. 1987. Excavation and Site Survey in the Huay Sai Khao Basin. *Bulletin of the Indo-Pacific Prehistory Association* 7: 94–117.

———. 1989. *Excavations at Non Pa Kluay, Northeast Thailand.* BAR International Series 517. Oxford: British Archaeological Reports.

Wilkins, A. S. 1997. Canalization: A Molecular Genetic Perspective. *Bioessays* 19: 257–62.

Wilkinson, J. C. 1987. *The Imamate Tradition of Oman.* Cambridge, U.K.: Cambridge University Press.

Williams, C. A. 1994a. The Bioarchaeology of the Cofferdam Site (22Lo599) in Lowndes Co., Mississippi. M.A. thesis, Department of Anthropology and Sociology, University of Southern Mississippi, Hattiesburg.

———. 1994b. Disease Profiles of Archaic and Woodland Populations in the Northern Plains. In *Skeletal Biology in the Great Plains*, ed. D. W. Owsley and R. L. Jantz, 91–108. Washington, D.C.: Smithsonian Institution Press.

Williamson, M. A. 1998. Regional Variation in Health and Lifeways among Late Prehistoric Georgia Agriculturalists. Ph.D. dissertation, Purdue University, West Lafayette, Indiana.

———. 2000. A Comparison of Degenerative Joint Disease between Upland and Coastal Prehistoric Agriculturalists from Georgia. In *Bioarchaeological Studies of Life in the Age of Agriculture: A View from the Southeast,* ed. P. M. Lambert, 134–47. Tuscaloosa: University of Alabama Press.

Wills, V., and J. Waterlow. 1958. The Death-Rate in the Age-Group 1–4 Years as an Index of Malnutrition. *Journal of Tropical Pediatrics* (March): 167–70.

Wilson, J. H. 1984. Charred Plant Remains. In *The Plum Grove Site (40WG17), Washington County, Tennessee, Cherokee National Forest,* ed. R. Dickens. Ms. on file, Laboratory of Archaeology, Georgia State University, Athens.

Wilson, K. J. 1997. Bioarchaeological Investigations of Late Archaic Stallings Island Culture: A Summary. *South Carolina Antiquities* 29: 1–16.

Wilson, M. L., and J. K. Lundy. 1994. Estimated Living Statures of Dated Khoisan Skeletons from the South-western Coastal Region of South Africa. *South Africa Archaeological Bulletin* 49: 2–8.

Wimberly, S. B., ed. 1960. *Indian Pottery from Clarke County and Mobile County, Southern Alabama*. Tuscaloosa: Alabama Museum of Natural History Paper 36.

Wolpoff, M. 1971. Metric Trends in Hominid Dental Evolution. *Case Western Reserve University Studies in Anthropology* 2: 1–244.

Wood, J. W., G. R. Milner, H. C. Harpending, and K. M. Weiss. 1992. The Osteological Paradox: Problems of Inferring Health from Skeletal Populations. *Current Anthropology* 33 (4): 343–70.

Wright, K. I. 2000. The Social Origins of Cooking and Dining in Early Villages of Western Asia. *Proceedings of the Prehistorical Society* 66: 89–121.

Wright, L. E. 1997. Ecology or Society? Paleodiet and the Collapse of the Pasion Maya.

In *Bones of the Maya*, ed. S.L. Whittington and D. M. Reed, 181–95. Washington, D.C.: Smithsonian Institution Press.

Wright, L. E., and F. Chew. 1998. Porotic Hyperostosis and Paleoepidemiology: A Forensic Perspective on Anemia among the Ancient Maya. *American Anthropologist* 100: 924–39.

Wright, L. E., and C. J. Yoder. 2003. Recent Progress in Bioarchaeology: Approaches to the Osteological Paradox. *Journal of Archaeological Research* 11 (1): 43–70.

Wright, M. H., D. C. Stout, and W. M. Bass. 1973. Skeletal Material from the West Site (40DV12), Davidson County, Tennessee. *Tennessee Archaeologist* 29: 12–50.

Wright, P. J. 2003. Paleoethnobotanical Analysis. *Plains Anthropology* 48: 51–58.

Wrobel, G. D. G. 2003. Metric and Nonmetric Dental Variation among the Ancient Maya of Northern Belize. Ph.D. dissertation, Indiana University, Bloomington.

Xi'an Banpo Museum (XBM). 1978. A Neolithic Site at Shijia in Weinan County, Shaanxi Province. *Kaogu* 1: 41–53.

———. 1982. *Weinan Beiliu Early Neolithic Site Bulletin.* Archaeology and Cultural Features 4.

Xi'an Banpo Museum (XBM), Shaanxi Institute of Archeology, and Lintong County Museum. 1988. *Jiang Zhai: Report on the Excavation of the Neolithic at Jiangzhai by the Excavation Group Site.* Beijing: Cultural Relics Publishing House.

Xueqin, Li, Garman Harbottle, Juzhong Zhang, and Changsui Wang. 2003. The Earliest Writing? Sign Use in the Seventh Millennium BC at Jiahu, Henan Province, China. *Antiquity* 77: 31–44.

Yakar, R., and I. Hershkovitz. 1988. The Modelled Skulls of Nahal Hemar. *Atiqot* 18: 59–63.

Yamamoto, M. 1992. Secular Trends of Enamel Hypoplasia in Japanese from the Prehistoric to Modern Period. In *Recent Contributions to the Study of Enamel Developmental Defects,* ed. A. H. Goodman and L. Capasso, 231–38. *Journal of Paleopathology* Monographic Publication 2.

Yan, Wenming. 1982a. Origin of Rice Agriculture in China. *Nongye Kaogu* 1: 19–31

———. 1982b. *The Study of the Yangshao Culture.* Beijing: Wenwu Press.

———. 1992. Origins of Agriculture and Animal Husbandry in China. In *Pacific Northeast Asia in Prehistory,* ed. C. M. Aikins and S. N. Rhee, 113–23. Pullman: Washington State University Press.

Yarnell, R. A. 1994. Investigations Relevant to the Native Development of Plant Husbandry in Eastern North America: A Brief and Reasonably True Account. In *Agricultural Origins and Development in the Midcontinent,* ed. W. Green, 7–24. Office of the State Archaeologist, Report No. 19. Iowa City: University of Iowa.

Yarnell, R. A., and M. J. Black. 1985. Temporal Trends Indicated by a Survey of Archaic and Woodland Food Remains from Southeastern North America. *Southeastern Archaeology* 4: 93–106.

Y'Edynak, G. 1989. Mesolithic Dental Reduction. *American Journal of Physical Anthropology* 78: 17–36.

Yuan, J. 2001. The most recent studies of early Chinese domestication. *Wenwu* 5: 51–58.

Yuan, J., and J. An. 1998. On Two Topics in the Zoo-Archaeological Research of China. *EAAnnouncements* 25: 8.

Yuan, J., and R. K. Flad. 2002. Pig Domestication in Ancient China. *Antiquity* 76: 724–32.

Zakharov, V. M. 1989. Future Prospects for Population Phenogenetics. *Soviet Scientific Review Series, Section F: Physiology and General Biology* 4: 1–7.

Zhang, J. 1986. Preliminary Discussion on Yangshao Times. In *Lun Yangshao Wenhua, Zhongyuan Wenwu* (special edition), ed. Henanshen Kaoguxuehui and Minchi Wenguanhui, 94–106. Beijing.

———. 1993. Racio-typological Study of the Human Skulls from the Cemetery of Kayue Culture at Lijiashan, Qinghai. *Kaogu Xuebao* 3: 381–418.

Zhang, J., and K. Han. 1998. The Observation and Identification of the People of Neolithic Age at Yuchisi, Anhui Province. *Acta Anthropologica Sinica* 17: 22–34.

Zhang, J., Xinghua Xiao, and Yun Kuen Lee. 2004. The Early Development of Music: Analysis of the Jiahu Bone Flutes. *Antiquity* 78: 769–79.

Zhang, Z., and L. Ziao. 1992. Study of the Hougang I Culture. *Kaogu Xuebao* 3: 261–80.

Zhou, B. 1981. Faunal Remains from the Cishan Site, Wu'an County, Hebei Province. *Kaogu Xuebao* 3: 339–46.

———. 1984. Domestic Animals of Chinese Neolithic Age. In *Archaeological Findings and Studies of New China,* ed. Archaeological Institute CASS, 196–210. Beijing: Wenwu Press.

Zhou, L., and R. S. Corrucini. 1994. Dental Enamel Hypoplasia and Historical Famine in China. *American Journal of Physical Anthropology* supplement 18: 214.

Zoubov, A. A. 1973. *Ethnic Odontology.* Moscow: Nauka.

Zuraina, M. 1982. The West Mouth, Niah, in the Prehistory of Southeast Asia. *Sarawak Museum Journal* 31: 1–200.

Zvelebil, M. 1998. Agricultural Frontiers, Neolithic Origins, and the Transition to Farming in the Baltic Basin. In *Harvesting the Sea, Farming the Forest,* ed. M. Zvelebil, L. Domanska, and R. Dennell, 9–29. Sheffield, U.K.: JR Collins.

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